

**ASSESSMENT OF FARMERS' PERCEPTION OF SOIL QUALITY WITHIN
THE ADA WEST DISTRICT OF THE GREATER ACCRA REGION OF GHANA**

BY

SARAH MAKU ADJOVU

(10599127)

**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN
PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF
MPHIL ENVIRONMENTAL SCIENCE DEGREE**



JULY, 2018

DECLARATION

I hereby declare that apart from the sources specifically acknowledged as contributions in the text, this work constitutes the results of my research and that it has not been admitted in part or in whole to any other university.

.....
Sarah Maku Adjovu
(Student)

.....
Date

.....
Dr. (Mrs.) Benedicta Fosu- Mensah
(Principal Supervisor)

.....
Date

.....
Dr. Ted Yemoh Annang
(Co-Supervisor)

.....
Date

DEDICATION

This work is dedicated to our Lord and Master Jesus Christ, Amen.

ACKNOWLEDGEMENT

My heartfelt gratitude goes to God almighty for his grace and mercy throughout this programme.

I also wish to thank my supervisors Dr. Benedicta Y. Fosu-Mensah and Dr Ted Yemoh Annang for their time and patience through the period of my project and all the sleepless nights they spent in supervising this thesis.

My dad and mum; Rev Stephen Lawer Adjovu and Mrs. Elizabeth Dede Adjovu for all their love and encouragement, I pray God's blessings upon them. I am also grateful to my husband Benjamin Tetteh Martey and siblings, Josiah, Elizabeth, Stephanie and Esther for being there for me.

My appreciation also goes to my wonderful aunties; Ms Mahela Narh and Ms Esther Narh not forgetting my late grandmother, Madam Sarah Maku Kabutey for all her encouragement and prayers.

I also appreciate Mr. Teye of the Ada-West district Agricultural Department, Gabriel, Angelbert, Konadu, Emmanuel and the farmers and people of Aditsirekope, Yomlekope, Zuenor, Fantevikope and Asigbeykope for their assistance during my data collection which has helped make my research a success. Not forgetting Mad Rosalind, Kojo, Mr Nyarko, Dinah, Ethel, Bro Moses and the workers of Ecolab (Mr Owusu, Christian, Gabriel and Samuel) who assisted me in analysing the soil samples, Boakye, Amoako, Solomon and Bright who assisted me with the statistical analysis. Not forgetting all those who supported me one way or the other.

To you all I say God bless you.

ABSTRACT

Globally, incorporating farmers' perception on soil quality indicators and its associated influence on soil management practices into policy decisions has become a topical issue in recent times. This study assesses the perception of farmers on soil quality within the Ada District of the Greater Accra Region of Ghana. Using a mixed method approach, 212 questionnaires were administered to farmers in five communities of the Ada West District. Thirty six soil samples were taken from four of the communities based on farmers' categorisation of soils into high, medium and low quality. Chemical test such as the pH, Electrical conductivity (EC), Total Nitrogen (N), available Phosphorous (P), Cation Exchange capacity (Mg, Na, Ca, K) were conducted on these soils which revealed that farmers could not accurately predict the quality of their soils as the nutrient content was generally low. Most of the farmers (64.8%) were of the view that climate change had an effect on their soil quality whereas only a few (18.1%) of them put in place any adaption measures. The most predominant farm yield management practice used was the application of organic soil amendments as farmers believed it increased crop yield rapidly. The study recommends that further training be organised for farmers on application rates of soil amendments. Climate change adaptation measures should be included in extension services.

LIST OF ABBREVIATIONS

FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
GSS	Ghana Statistical Service
PCA	Principal Component Analysis
ORM4 SOIL	Farmer-Driven Organic Resource Management to Build Soil Fertility Research
SDG	Sustainable Development Goals
SPSS	Statistical package for Social Scientist
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WHC	Water Holding Capacity

TABLE OF CONTENT

DECLARATION.....	i
DEDICATION.....	ii
ACKNOWLEDGEMENT.....	iii
ABSTRACT.....	iv
LIST OF ABBREVIATIONS	v
TABLE OF CONTENT.....	vi
LIST OF TABLES	ix
TABLE OF FIGURES.....	x
CHAPTER ONE	1
GENERAL INTRODUCTION.....	1
1.1 Background to Study	1
1.2 Objective	4
1.3 Justification	4
CHAPTER TWO	6
LITERATURE REVIEW	6
2.1 Soil quality	6
2.1.1 Soil quality and plant growth.....	7
2.2 Soil quality indicators	8
2.2.1 Physical indicators of soil quality	8
2.2.2 Biological factor that indicates soil quality	10
2.2.3 Chemical indicators of soil quality	11
2.3 Indigenous soil quality indicators used by farmers.	13
2.3.1 The use of weeds as soil quality Indicators	15

2.4	Measuring soil quality levels as against perceived quality levels	16
2.5	Climate Change.....	17
2.5.1	Linkages between climate change and agricultural production	18
2.5.1	Climate Change and soil quality	21
2.5.2	Agricultural adaptations to climate change.....	22
2.6	Farm management practices associated with yield improvement.....	24
CHAPTER THREE		26
MATERIALS AND METHODS		26
3.1	Study Area	26
3.2	Study Design	29
3.3	Sources of data	29
3.4	Social survey	29
3.4.1	Sample Size.....	30
3.5	Assessment of soil parameters	30
3.5.1	Soil sampling method.....	30
3.5.2	Soil sample preparation.....	31
3.5.3	Soil pH determination	31
3.5.4	Soil Electrical Conductivity	32
3.5.5	Soil particle size distribution	32
3.5.6	Soil organic carbon	34
3.5.7	Total Nitrogen.....	35
3.5.8	Available phosphorus.....	35
3.5.9	Extraction of Exchangeable bases (Ca, Mg, Na, K).	36
3.6	Data analysis.....	38
CHAPTER FOUR.....		39
RESULTS		39
4.1	Demographic Characteristics of Respondents	39
4.2	Identification of Indigenous Soil Quality Indicators Used by Farmers	41
4.2.1	Association between soil quality indicators and demographic data	46
4.3	Assessment of farmer based soil quality status	49
4.3.1	Assessment of the quality of soils using physical soil indicators	49
4.3.2	Chemical assessment of soil quality	50

4.3.3	Synthesis of soil quality difference based on soil attributes	52
4.3.4	Soil variability using Principal Component Analysis	53
4.4	Farmers perception on the effect of climate change on soil quality	54
4.4.1	Binary Regression on factors that influence farmers perception on impact of climate change on soil quality.....	58
4.5	Soil management practises used by farmers	60
4.5.1	The use of soil amendments.....	61
4.5.2	Association between demographic characteristics and soil amendments used	64
CHAPTER FIVE		65
DISCUSSION OF RESULTS		65
5.1	Assessment of farmer based soil quality status	65
5.2	Assessment of soil quality status using physical soil indicators.....	66
5.2.1	Assessing soil quality status using chemical soil indicators	67
5.2.2	Synthesis of soil quality difference based on soil attributes	67
5.2.3	Soil variability using Principal component analysis.....	68
5.2.4	Implications of evaluating farmer knowledge with scientific measurements...	69
5.3	Farmers’ perception of climate change on soil quality.	69
5.4	To assess farmers management practises	71
CHAPTER SIX		73
SUMMARY OF STUDY FINDINGS, CONCLUSION AND RECOMMENDATION		73
6.1	Summary.....	73
6.2	Conclusion	74
6.3	Recommendation.....	75
REFERENCE.....		77
APPENDIX.....		84

LIST OF TABLES

Table 2.1.: Standard soil parameter ranges	13
Table 4.1 Demographic characteristics (n=212).....	40
Table 4.2 Plants and weeds used as soil quality indicators	45
Table 4.3 Most important soil quality indicator to farmers.....	45
Table 4.4a Showing Association between demographic Characteristics and soil quality indicators	47
Table 4.4b Showing Association between soil quality indicators and demographic data.....	48
Table 4.5: Soil particle size distribution	50
Table 4.6: Chemical indicators of soil quality categories.....	51
Table 4.7: Factor loadings of soil physicochemical parameter.....	54
Table 4.8 Perceived effects of Climate Change on soil quality	58
Table 4.9: Factors that influence farmers perception on climate change impact on soil quality.....	59
4.11 Association between demographic characteristics and the users of soil amendments.....	64

TABLE OF FIGURES

Fig. 2.1 Diagram showing plants nutrients availability relative to soil pH as illustrated by the width of the bands width. Source: Boggs (2016).....	12
Fig 3.1 Study area map.....	27
Fig. 4.1 Percentages of perceived soil type.....	42
Fig.4.2 Number of farmers who use the individual soil quality indicators to determine soil quality.....	43
Fig.4.3 An average annual temperature from 1988-2012 of the Ada area showing an increasing trend in annual temperature (Source: Ghana Meteorological Service)..	56
Fig.4.4 An average annual rainfall from 1988-2012 of the Ada area showing an increasing trend in annual rainfall.....	57
(Source: Ghana Meteorological Service)	57
Fig. 4.5 Farm yield management practices	60
Fig. 4.6 Farmers’ choice of soil amendments	62
Fig.4.7 Famers source of information on soil amendments application rates.....	63

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background to Study

Farming can be described as one of the oldest professions in the world, which ensures continuous food supply to meet the needs of the people. Sufficient and continuous availability of food is an important factor to ensuring the survival of man since it provides him with the essential nutrients for life and also acts as a source of raw materials to feed various industries (Mirzaei-Aghsaghali & Maheri-Sis, 2008).

The UNDP's decision to include food security in its Sustainable Development Goals (SDG) is a good initiative. The focus of the Sustainable Development Goals, goal number 2 (SDG 2) is zero hunger which has the aim of ensuring food security through the promotion of sustainable agriculture which will improve nutrition and in the long run help end hunger (Griggs *et al.*, 2013). This particular goal seeks to end hunger and to do so, it is to be ensured that food is made available to all, regardless of age or location.

Most developing countries' economies thrive on agriculture with Ghana being no exception. Ghana's economy is considered as agrarian, this is largely due to the sector's high contribution to Gross Domestic Product (GDP) (GSS, 2014). The agricultural sector contributed about GHC 26,133.6 million in 2015 and GHC 29,565 million in 2016 which indicates an increase of about 3% contribution of agriculture to the country's GDP (GSS 2017). This in turn implies an increasing usage of soil resources which makes it necessary to identify soils of good quality to optimize agricultural productivity.

In crop production, climate and the soil are important factors as they highly influence the growth, development and yield of crops (Chesworth, 1982). Meanwhile the climate keeps changing under natural and anthropogenic forces which is likely to have an effect on the soil and hence crop production (Seneviratne *et al.*, 2010). Soil is essential for crop production as it provides the medium in which plants grow. Knowing your soil and how to maximise its potential is necessary to ensure optimum productivity of the land. In view of this the key factors that could determine if this goal of zero hunger could be met are climate and soil quality. In agriculture, soil quality is often described based on the ability of a soil to support agricultural productivity (Karlen *et al.*, 1997). Therefore adequate knowledge on the quality of the soil is necessary since it is a deciding factor on which soil to plant on, the type of crop that could be cultivated and the best management practices to increase productivity.

Soil quality does not always remain the same; it either improves or deteriorates overtime depending on activities and processes that take place on it. Soil quality properties (indicators) which are used to determine the quality of a soil are basically grouped under physical, chemical and biological indicators (Boggs, 2016). Periodic testing of soil quality is essential to determine the state of soils which will in turn help in deciding which land will be more suitable for agricultural productivity, what type of crops could be planted as well as the best management practices to employ. Nevertheless most farmers depend on their local knowledge acquired over the years in determining the quality of their soils. This is due to their level of knowledge of the available scientific parameters of checking for soil quality, the cost of accessing such facilities and the accessibility of laboratories for such purposes. This has led to the development of diverse views and perceptions used in

determining the quality of soils. These views and perceptions of local farmers on soil quality are usually based on local knowledge often passed on from the older generation, through experience and therefore though some of these perceptions may be applicable to one area, in other areas there may be some differences.

Though over the years farmers have adapted several soil quality indicators based on their indigenous knowledge and perceptions in determining the quality of their soils, these issues still remain; what extent are these indicators accurate? How could the scientific and indigenous soil quality indicators be married? Is climate change really having an effect on the soils? How are farmers dealing with it?

This study sought to assess the perception and indigenous knowledge of farmers within some selected communities namely: Zuenor, Asigbeykope, Aditsirekope, Yomlekope and Fantevikope within the Ada-West District of the Greater Accra Region of Ghana on indicators they use to determine the quality of their soils, their view on climate change and soil quality while looking at management practices that are put in place to promote increase the productivity of their soils.

There have been some works done in relation to the assessment of farmers' perception on soil quality. However, this study combined indigenous perceptions held by farmers on soil quality indicators and scientific analysis of soil parameters, to confirm or otherwise the farmers' assertions in relation to soil quality and the perceived effect of climate change on soil quality. This would in turn go a long way to help researchers and agricultural extension officers better understand the farmer's approach to identifying soil quality hence promote subsequent efforts to integrate local farmers' knowledge with scientific knowledge

(Tesfahunegn *et al.*, 2011). Knowledge that will be derived from this study will also serve as a guide or reference material for future research works related to this study. Hence there is the need to undertake this study on farmers' perception on soil quality indicators and the perceived effects the changing climatic elements has on soil quality.

1.2 Objective

The study's main objective was to assess the perception of farmers on soil quality indicators and the perceived effects that climate change has on soil quality.

The specific objectives of this study are;

- Identify indigenous soil quality indicators used by farmers.
- Compare the assessment of farmers' soil quality with laboratory analysis.
- Find out farmers' perception on the effects of climate change on soil quality.
- Assess farmers' soil management practises used by farmers within the study area.

1.3 Justification

Most of the inhabitants of the Ada-West District are employed within the Agricultural sector (GSS, 2014) of which about 43% are engaged in crop farming. Farmers over the years have developed many ways of identifying soils of good quality for agricultural purposes using indigenous indicators of soil quality. Nevertheless, there are scientific means of determining the quality of soils but local farmers find it more convenient using indigenous indicators of soil quality as they are readily available.

Recent efforts by researchers have been to find ways of synchronising indigenous knowledge of soil quality indicators with the use of laboratory testing of soils. Though some

researchers have found the use of indigenous soil quality indicators to be accurate, this study employed a mixed method approach to ascertain whether it was so in the Ada West District as farmers are continuously faced with the effects of the gradually changing climate. In view of this, it was expedient for farmers to classify soils into high, medium or low soil quality. Samples of which were collected and tested to enable the verification of the perceived soil qualities. As perceptions on climate change as well as farm management practices have influence on soil quality, aspects of them are included in this study

CHAPTER TWO

LITERATURE REVIEW

A review of relevant literature is presented on pertinent issues on soil quality, soil quality indicators, indigenous soil quality indicators, the effects of climate change and farm yield management practices.

2.1 Soil quality

Boggs (2016) defined soil as the foundation upon which plants are built. This makes the soil an important requirement upon which plants depend for growth and development as it holds and supports the plant. The state of the foundation determines how what is developed on it (i.e. plant) will be, as the nature of the foundation is exhibited in the characteristics of the plant (McKeague, 1978). This is because the plant derives most of its nutritional needs from the soil. Therefore the plant absorbs whatever is available in the soil which influences its growth, development and yield.

The quality of a soil is often defined based on the purpose or function it is meant to perform, as each purpose for which it is to be put to have a specific requirement (Karlen *et al.*, 1997). As such how the quality of a soil may be described in one field may differ from another. Therefore in relation to the functional requirements of a soil, it could be described as a good or bad quality soil. When the requirements are adequately met, it may be described as a good quality soil but when some of its requirements are lacking it may be referred to as a bad quality soil. Inferring from the above a good agricultural soil may be a bad pottery soil as they all have different requirements.

Warkentin (1995), describes soil quality as a changing concept and as such a further refinement to its definition is to look at it from the perception of the various ecosystem functions it performs.

One of the definitions of soil quality often used is, ‘the soil with the capacity to perform a specific function, within a natural or managed environment to sustain the production of plants and animals in order to maintain or improve the quality of air and water to support human health and livelihoods (Karlen *et al.*, 1997). This definition combines the varying soil requirements of various fields. McKeague (1978), defined soil quality in its simplest term as; “the capacity of soil to function”. Soil quality in agriculture could therefore be described as a soils’ capacity to support agricultural plant processes. As such this study was concerned with assessing agriculture soil quality.

2.1.1 Soil quality and plant growth

Boggs (2016) quoted Robert Frost as saying, “A trees’ leaves may be ever so good the crops grown on it will develop and reproduce”. Therefore a plant not doing well on a particular soil may be as a result of what is at the root. In other words, the soil quality determines the rate of growth and development of the plant it supports.

Knowing ones soil and the regular assessment of the likely changes that might have occurred to the status of the quality of the soil with time is necessary to assess the possible impacts that the various management practices might have had on it (Arshad & Martin, 2002). This suggests that the various management practices have impact on the soils, which may either be positive or negative and as such periodic testing of soils can help in determining these impacts.

According to Normaniza *et al.* (2018), one factor that promotes plant growth and development is a soil with the presence of microbes which promote nutrient intensification and soil-root enhancement, and has the tendency of reducing soil erosion.

Agegnehu (2017), also indicated that soil quality such as plant nutrient and soil nutrient concentrations as well as soil water content, after harvesting is highly correlated with plant growth and development in terms of shoot and root biomass.

2.2 Soil quality indicators

According to Boggs (2016), soil quality properties which are used to determine the quality of a soil are basically grouped under physical, chemical and biological indicators. Schoenholtz *et al.* (2000) further went ahead to say that separating soil functions into chemical, physical and biological processes often becomes a difficult task as these processes are not just dynamic but also interactive. A similar statement was made by Arshad & Martin (2002) that, most of the indicators of the quality of a soil interact with each other, and therefore, making the value of one susceptible to be influenced by the other parameters. In other words, identifying these soil indicators is key to assessing the quality of farm soils.

2.2.1 Physical indicators of soil quality

Schoenholtz *et al.* (2000) stated that processes and functions of the physical properties of soil include the ability of a soil to “promote root growth, accept, hold, and supply water and mineral nutrients, promote optimum gas exchange, promote biological activity and finally accept, hold, and release carbon”. Schoenholtz *et al.* (2000) further stated that, the texture of a soil, its depth, the bulk density, its ability to hold water, the roughness of the

soil its tilth, leaching potential, erosion potential among others as the physical indicators of soil quality. And as such to be able to assess the quality of a soil it is expedient to identify the texture of the soil.

Brejda *et al.* (2000), also indicated that physical indicators of soil quality can include soil structure, soil colour, soil texture (proportion of sand, silt and clay) and resistance to erosion. Whereas according to the FAO (1998) although soil colour is easily discerned it is influenced by the interplay, the soil's drainage, organic matter content and its degree of oxidation and as such has little use in predicting soil characteristics but rather beneficial in identifying the source of parent material of soils, determining a soil profile's boundaries, as an indication of the soils' water retention characteristics, and also as a means of evaluating the carbonate, salt and organic contents of soils.

Naiman *et al.* (2005), in their study found that the texture of a soil is the most important physical property of soil, as it controls processes such as carbon, oxygen, water and nutrient retention, exchange and uptake. Thus the texture of a soil is a key indicator among the physical soil properties that affect the other soil properties and processes.

Roy *et al.* (2006) in their book, "Food nutrition for Food Security", described the various soil textures with respect to nutrient and water holding capacity. They described sandy soils generally as being poor in nutrients and had low water holding capacity, but provided good conditions for root growth, soil aeration and drainage of surplus water. On the other hand, clayey soils were described as often being rich in nutrient reserves, had high water holding capacity because of the many medium and small pores, but soil aeration was restricted. In terms of crop production, loamy soils like silty loam and sandy loam were generally most

suitable as they tend to have intermediate properties. It is therefore necessary to identify the texture of the soils in this study as it sheds light on the characteristics of the texture of the different soil likely to be found in the study area.

2.2.2 Biological factor that indicates soil quality

The Food and Agricultural Organisation of the United Nations (1974) looks at biological factors used as soil quality indicators as “those soil properties related to the microbial and faunal activity in soil which include earthworms, nematodes, protozoa, fungi, bacteria and different arthropods.

Dawoe *et al.* (2012), in their work on soil fertility management also defined biological indicators of soil quality as plants (other than crops) or animals whose presence or growth reflected soil fertility status.

Whereas Krüger *et al.* (2017) also defined biological indicators of soil quality as organisms or biological processes which provide early diagnosis of changes within the environment and as such in soil quality analysis, their presence or absence could be used as good indicators of the state of a soil. They further indicated that, soil organisms and their activities were essential for the soil ecosystem functioning and they could thus be used as pertinent indicators of soil quality.

As such, identifying such biological indicators in terms of the presence of some plants weeds and soil living organism within the study area of this research will be beneficial in identifying the quality of the soils.

2.2.3 Chemical indicators of soil quality

The findings of Schoenholtz *et al.* (2000) summarised the chemical soil quality indicators to include: Organic carbon, Organic matter, pH, EC, CEC, Nutrient availability (soil N, P, K) among others.

According to Roy *et al.* (2006), there are sixteen nutrients which are usually grouped into macro and micronutrients which are essential for plant growth and development as well as living organisms in the soil. They described those that were the most essential nutrients to plant development and needed in high quantities as macronutrients which included Carbon (C), Oxygen (O), Hydrogen (H), Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulphur (S). Whereas those which were crucial for plant development and growth and yet needed in smaller amounts as micronutrient, these include Iron (Fe), Zinc (Zn), Manganese (Mn), Boron (B), Copper (Cu), Molybdenum (Mo) and Chlorine (Cl)".

According to Thomas (1996), the pH of a soil could tell a lot more about the soil's characteristics especially the availability of nutrients as well as the toxicity of other elements in a soil. This was confirmed by Schoenholtz *et al.* (2000) in their assertion that most chemical reactions that have the tendency to affect nutrient availability such as chemical form, adsorption, precipitation are influenced by the chemical environment of the soil, and soil pH in particular. This confirms the relationship between the availability of minerals and the soil pH as shown in Fig.2.1. Meanwhile according to Boggs (2016), the closer the pH of the soil is to the neutral value, the higher the rate of nutrient availability in the soil.

According to Roy *et al.* (2006), most plants thrive in the neutral to slightly acid pH range (pH 6–7) with Ca being the dominant cation. Meanwhile in terms of nutrient mobilization, between pH range of slight and moderately acidic could have special advantages (Roy *et al.*, 2006). It is therefore necessary to include the identification of the pH of soils in studies that assess the quality of the soils.

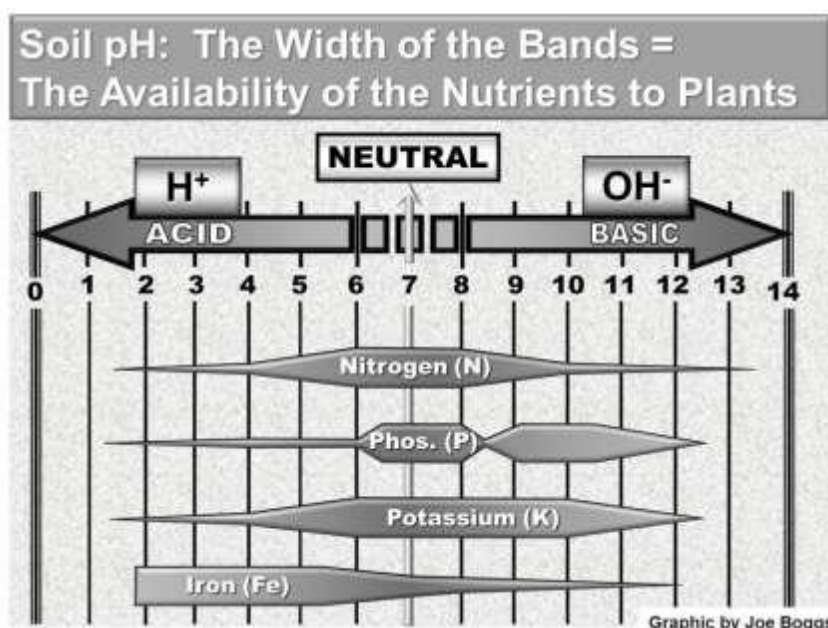


Fig. 2.1 Diagram showing plants nutrients availability relative to soil pH as illustrated by the width of the bands width. Source: Boggs (2016)

Proffitt, T. (2014) stated standard ranges for specific soil parameters, within which these parameters could be regarded as either been of high medium or low concentrations within soils (Table 2.1).

Table 2.1.: Standard soil parameter ranges

Parameter	Low	Moderate	High
Ca(cmol+)/kg)	<5	5-10	>10
Mg(cmol+)/kg)	<1	1-5	>5
Na(cmol+)/kg)	<0.3	0.3-1.0	>1
K(cmol+)/kg)	<0.5	0.1-1.0	>1
OC (%)	<1.0	1.0-1.8	>3.0
OM (%)	<0.9	0.9-1.7	>1.7
Nitrogen (mg/g)	<1	1-2	>10
Phosphorous (mg/g)	<0.25	0.25-0.8	>0.8
EC	0-11	1.2-4.4	>4.5

Source: Proffitt, T. (2014).

2.3 Indigenous soil quality indicators used by farmers.

Winklerprins (1999) defined local or indigenous soil knowledge as “the knowledge of soil properties and management possessed by people living in a particular environment for some period of time”.

According to Tesfahunen *et al.* (2011), the quality of soils were categorized by indigenous farmers based on easily recognizable features, which are often transmitted from one generation to another. As such it is therefore necessary to identify such soil quality indicators used by indigenous farmers.

Lima *et al.* (2011), identified earthworms, the colour of soils, crop yield, vigorous vegetation growth, soil organic matter, the root development of crops, soil friability, plant growth and development and colour of the plant as the soil quality indicators used by the farmers in determining the quality of their soils. Out of these, vigorous vegetation growth,

soil colour and plant growth and development were the indicators found to be very useful to the farmers in deciding what to grow on their lands and the soil amendments to apply:

Omari *et al.* (2018) in their work; “*Exploring farmers' indigenous knowledge of soil quality and fertility management practices in selected farming communities of the Guinea Savannah agro-ecological zone of Ghana*”, also identified indicators of soil characteristics in which farmers used to perceive soil health to include mainly the soil colour, nutrient composition, the presence or absence of soil organisms, the texture, tillage as well as the compaction of the soil.

The key indicators that were mentioned by farmers in a similar work done in the Ashanti region of Ghana by Dawoe *et al.* (2012), were, crop yield, water holding capacity, soil colour, presence of fresh worm casts, soil macro-fauna, weeds, rocky soil, the growth and height of leaves. Whereas the colour of the soil was described as the most significant determinant of soil quality to the farmers (Dawoe *et al.*, 2012).

The farmers within the Mai-Negus catchment in the northern part of Ethiopia also agreed on similar indicators of soil quality as those indicated above. These included the performance and yield of crops, soil depth, colour, susceptibility of a soil to erosion and the fertility of the soils based on which they categorized the soils into different status such as low, medium as well as high quality soils (Tesfahunegn *et al.*, 2011).

From the foregoing, it could be realised that the use of soil colour to indicate the quality of soils ran through. This could imply that though there is the possibility of farmers in different parts of the world including Ghana, using all the other indicators, soil colour is more likely to be widely used in indicating the quality of soils.

From the literature reviewed above on the indigenous soil quality indicators used by farmers, it could be realised that most of them were either physical or biological indicators of soil quality. This could be because it did not involve any rigorous scientific procedures in using them in detecting the quality of soils. Hence identifying such indicators will help achieve the objective of identification of indigenous soil quality indicators used by farmers in this study.

2.3.1 The use of weeds as soil quality Indicators

Hill and Ramsay (1977) stressed on the use of weeds as soil quality indicators. In their study, they suggested that, the colour and growth pattern of vegetation and leaves of some plants may be crucial in assessing the state of the soil. The study further revealed the importance of weeds in ensuring the quality of soils as they serve as a protection for the top soil against erosion and the direct rays of the sun while their roots penetrate the soil to ease the penetration of the roots of other plants thereby also improving soil aeration. (Hill & Ramsay, 1977).

In the study of Omari *et al.* (2018) within the Guinea Savannah area of the Northern Region of Ghana, farmers asserted that they used some plants and weeds such as *Andropogon gayanus*, *Panicum maximum*, *Imperata cylindrical* and *Centrosema pubescens* among others as signs of good soil quality whereas *Cyperus rotundus*, *Digitaria horizontalis* and *Striga hermonthica* were indicators of unhealthy soils.

Tesfahunegn *et al.* (2016), from their study suggested that since farmers were good at the identification and use of weeds as soil quality indicators, they should be encouraged to do

so. Thus, identifying these plants and weeds could serve as a simpler method of identifying the quality of soils.

2.4 Measuring soil quality levels as against perceived quality levels

Knowledge of soil quality does not end with just perceptions but should include scientific backing. In the research findings of Dawoe *et al.* (2012) on “*farmers’ local knowledge and perceptions of soil fertility and management in the Ashanti Region of Ghana*”, the farmers grouped the soils into fertile and infertile soils. Chemical analyses such as the detection of soil pH, Nitrogen, Phosphorus, potassium and organic matter content were conducted on samples of soils collected within the two identified groups.. According to their work, the pH of the soils sampled ranged from strongly to mildly acidic. According to the findings of Dawoe *et al* (2016), higher values of organic matter content, nitrogen, phosphorus and potassium and were reported in fertile fields as compared to the infertile fields. Therefore he concluded that, “there was a strong similarity between the farmers’ assessment of fertility on their fields and the determined soil properties”.

Unlike the study conducted by Dawoe *et al.* (2012) where farmers classified soils into fertile and infertile soils, the study by Tesfahunegn *et al.* (2011) on soil quality, soils were grouped by the farmers into “high”, “medium” and “low” quality. Based on the farmers’ classification of the soils, samples were collected and subjected to soil chemical analysis. Adapting the classification of soils into three categories by the use of an intermediary classification might help in bringing out the perceptions more clearly.

In the findings of Tesfahunegn *et al.* (2011), which are similar to that of Dawoe *et al.* (2012), the trend of the measured indicator values were well-fitted with the trend of soil quality categories done by the local farmers. This according to him meant that, moving from low to high soil quality category, measured levels of soil chemical indicators increased in ascending manner, more especial within the soil nutrient. It is therefore necessary for this study to follow a similar approach of soil classification by farmers and laboratory testing of soils to ascertain whether farmers in the Ada-West District were able to predict the quality of their soils accurately.

Tesfahunegn *et al.* (2011), also used principal component analysis to derive the factor loadings to derive four principal components, They labelled the first Principal component (PC) as “soil nutrient and soil structure factor”, the second principal component as “soil texture factor”, the third principal component as “soil total phosphorus and reaction”, and the fourth principal component as “Ca:Mg factor”. This helped in identifying the parameters that influenced the quality of the soil the most therefore this study uses this same procedure in its analysis.

2.5 Climate Change

Climate Change could be described as long-term changes in the mean temperatures or rainfall, which is reflected in increased frequency of extreme climate conditions with its resulting effects’ (Kurukulasuriya & Rosenthal, 2013). Seneviratne *et al.* (2010) described the climate as being under the influence of natural and anthropogenic forces making it continuously changing. Thus climate change did not occur in just a day, but its effects are visible as a result of a gradual process which became heightened. This could be attributed to the unimpeded increase in the emission of greenhouse gas which has contributed to the

earth's temperature rising, thus resulting in consequences such as the melting of ice-sheets, increasing precipitation, increasing occurrence of extreme weather events, and shifting of seasons (Nelson *et al.*, 2009).

Notably, the definition of climate change by the United Nations Framework Convention on Climate Change (UNFCCC) limits it to changes that are directly or indirectly attributed to human activities and to natural climate variability (Bodansky, 1993). Thus the foregoing discussion confirms the assertion that globally climate is changing and as such the climate of the Ada West District is no exception.

2.5.1 Linkages between climate change and agricultural production

Climate variation could result in the occurrences of extreme climatic events such as drought and flooding which create unforeseen uncertainties in Agricultural productivity (Kurukulasuriya & Rosenthal, 2013). These authors further described the expected effects of climate change to include, shortage of water and other resources, worsening soil conditions as a result of drought which has the potential to influence desertification, increase disease and pest outbreaks on crops and livestock, among others. The findings of McCarthy *et al.* (2001) indicates that the emerging effects of variations in the climate are diverse and not directed towards just one area but includes health, natural resources as well as agriculture, as some factors that influence agriculture are evidently affected. From the effects of climate change stated above it could be deduced that the changing climate affects man, plants, as well animals and as such, the environment as a whole. One effect may give rise to the other making some of them interconnected. Thus with the worsening soil conditions crop yield will be affected negatively.

According to Darwin *et al.* (1995), the changing climate is likely to influence geographic shifts in agricultural production and structure, but it is not significantly likely to affect the world food production level. They further emphasised that the emerging effects of climate change on soil quality may differ from place to place as the different climatic zones are expected to experience different conditions such increase in the availability of land suitable for agricultural activities in the arctic and mountainous areas, whereas in the tropical regions warming is likely to reduce soil moisture, thereby having a negative effect on agricultural productivity (Darwin *et al.*, 1995). The implication of the above is that climate change effects may favour agricultural activities in some places whereas in other places the conditions may get harsh for agricultural productivity therefore having both beneficial and adverse effect. As Ghana is within the tropical area, the Ada West district from this literature is likely to experience harsh conditions such as reduction in soil moisture which will affect agricultural productivity negatively.

According to Bodansky (1993), “adverse effects of climate change” as defined by the UNFCCC does not take into consideration the direct or indirect costs of climate change mitigation measures, rather it limits it to changes in the physical environment or biota that have evident deleterious effects. Thus it is expedient to look out for the possible effects that climate change might have on agricultural productivity in the study area.

Kurukulasuriya & Rosenthal (2013) also asserted that, variations in mean temperature and precipitation is likely to change the distribution of agro-ecological zones, thus influencing variations in soil moisture content; timing and length of growing seasons in different parts of the world.

According to Adams *et al.* (1998), climate variation could have both positive and negative influence on crop yield and that temperature increases have been found to reduce yields and quality of many crops, and particularly, cereal and feed grains. They further stated that precipitation variability in terms of level and timing may benefit semi-arid and other water-short areas by increasing soil moisture, but could aggravate problems in regions with excess water, whereas a reduction in rainfall could have the opposite effect.

Emphasising the potential of climate change to increase the spread of pest and diseases, Piao *et al.* (2010), asserted that climate change had the tendency to expand the geographic ranges of pests and diseases by creating more conducive environments for them. This will in turn increase the stress on crops, thereby affecting agricultural productivity negatively.

In the same view, Adams *et al.* (1998) also stated that Climate change had the tendency to affect the availability and timing of irrigation water supplies; the severity of soil erosion as well as the types, frequencies and intensities of various crop and livestock pests.”

Economically, the resulting changes in temperature and precipitation has a tendency in altering crop yields as the water requirements for irrigation of crop is affected (Adams, 1989). Therefore increases cost of production as more effort has to be put into irrigating the farms, thus reflecting a negative effect of climate change on farming activities.

According to the findings of Deressa *et al.* (2011) in their work on the perception and adaption to Climate change, the perception of farmers on climate change was significantly influenced by the age of the head of the household, wealth, knowledge of climate change, social capital and agro-ecological settings.

The study of Tesfahunen *et al.* (2016), revealed that the perception of farmers on climate change was strongly influenced by their experience in the management of their soils and their access to harvested water for agricultural purposes.

2.5.2 Climate Change and soil quality

According to Nearing *et al.* (2004), Climate Change has the potential of affecting soil microbial activity, plant residue decomposition rates as well as resulting in increasing rates of rainfall related erosion activities. Important soil microbial activities such as nitrification organic matter decomposition are likely to be affected by the changing climate as these microbes are sensitive to temperature changes (Classen *et al.*, 2015). They further stated that soil moisture is also likely to be affected, since temperature changes has an effect on soil moisture hence affecting the rate diffusion and transportation of important nutrients within the soil.

Increasing precipitation related to climate change has the tendency to result in increasing surface runoffs which will lead to land degradation hence affecting the quality of the soil which will in turn negatively affect agricultural productivity (I. P. O. C.C, 2001). Thus quality of soils are negatively affected as soil materials are eroded.

According to Davidson *et al.* (2006), flooding of soils has the tendency to reduce oxygen supply for the decomposition of residues within the soil, hence making it quite impossible for aerobic decomposition to take place. Though anaerobic decomposition could take place these processes are mostly slow Also in cases where soil water gets frozen, diffusion of substrates are slowed down affecting the activities of enzymes within the soil (Davidson *et*

al., 2006). Thus the changing climate has the tendency to affect soil processes, hence the quality of soils

2.5.3 Agricultural adaptations to climate change

The effects of climate change are inevitable; therefore the purpose of undertaking agricultural adaptation is to effectively manage the potential climate risks (Howden *et al.*, 2007).

Howden *et al.* (2007) identified the following as ways of crop system adaptation:

- Using alternative seed variety and species such as those which are more heat and drought resistant
- Managing the use of fertilizer, timing irrigation and other water management practices to ensure soil quality consistent with the prevailing climate.
- Adapting effective water harvesting technologies to supplement and conserve soil moisture
- Managing water to prevent water logging, erosion, and nutrient leaching where rainfall increases,
- Altering the timing or location of cropping activities,
- Diversification of income through the incorporation of other agricultural activities such as livestock rearing while ensuring effective control and management of pest and weeds, to reduce incurring production losses.

In the study of Deressa *et al.* (2009) on the “*Determinants of farmers’ choice of adaptation methods to climate change in the Nile Basin of Ethiopia*”, the climate adaptation methods used by farmers included planting trees, soil conservation, the use of different crop

varieties, changing planting dates and irrigation whereas some of them did nothing. It was also realised from their study that the use of different crop varieties was the most predominant adaptation strategy. Reasons given by farmers who did not put in any adaptation strategy included lack of information, lack of money, shortage of labour, shortage of land, and poor potential for irrigation (Deressa *et al.*, 2009).

The findings from the study by Fosu-Mensah *et al.* (2012) in Sekyedumase of Ghana identified the adaptation strategies used by local farmers to include diversification of crop, planting of short season varieties, changing the species of crops and a shift in planting date, among others.

According to the findings of Deressa *et al.* (2011) on “*perception of adaptation to climate change*”, factors such as the education of the household head, household size, gender of the head of the household, whether livestock were owned, the use of extension services on crop and livestock production, the availability of credit and the environmental temperature as significantly affecting adaptation to climate change. On the other hand, Fosu-Mensah *et al.* (2012) identified access to extension services, credit, soil fertility, and land tenure as the factors that influenced farmers’ perception on climate change and adaptation the most. Maddison (2007) and Yaro (2013) also found that, those with the greatest experience of farming are more likely to notice climate change. From their findings, significant numbers of farmers with increasing years of experience believed that temperatures have already increased and that precipitation has declined with its resultant effects on soils. Okonya *et al.* (2013) also found out that in Uganda, farmland size and the household head’s gender significantly influenced the adaptation of farmers to climate change.

2.6 Farm management practices associated with yield improvement

According to Dawoe *et al.* (2012), the widely used fertility management practices in the Ashanti Region of Ghana included, slash and no burn, application of crop residues, retention of selected trees on farmlands, poultry manure, inorganic fertilizer application, minimum tillage and fallowing. According to Dawoe *et al.* (2012) findings, only a small percentage of farmers use inorganic fertilizers, giving their lack of purchasing power as their reason for its low patronage.

Meanwhile the findings of Omari *et al.* (2018) indicated that farmers in the Guinea Savannah areas of Northern Ghana preferred the use of inorganic fertilisers. They further indicated that this choice of farmers to use inorganic fertilisers over the other fertilization practices stemmed from its high crop response, accessibility, it being a common practice in the communities.

The findings of Zhen *et al.* (2006) in their study conducted in the North China plains showed that most farmers preferred a soil-fertility practice in which both organic and chemical fertilizers were combined followed by those who preferred organic fertiliser and inorganic fertiliser, respectively. To the farmers, combining both the organic and inorganic fertiliser had a significant positive effect on their crop yield and has the potential of increasing the fertility of their soils over time. According to Zhen *et al.* (2006), the use of fertiliser is unbalanced in the area as potassium and organic fertilisers are insufficiently used. Meanwhile, Nitrogen and Phosphorous are overused which has negatively impacted the quality of groundwater and contaminated vegetables with nitrate. However Tilman *et al.* (2002) and Zhen *et al.* (2006), recommend that tests be run on soils and plants to adjust soil amendment application rates to crops to reduce excessive nutrient input while adopting

appropriate decision support systems to promote efficient and sustainable management of production resources.

Mapfumo and Giller (2001), emphasised that the management practices that is currently the most viable source of nutrient is manure and crop residues as this is more eco-friendly. When safeguarding the environment the soil amendments to be considered must be one which is eco-friendly as Mapfumo and Giller (2001) stated and for this study organic amendments are the key. Tilman *et al.* (2002), also stated that globally food production was increasing and as such, policies to ensure agricultural sustainability should be put in place.

This study therefore sought to assess farmers' perception of soil quality indicators used by indigenous farmers in the Ada West District of Ghana to identify how different or similar these findings are. This will be achieved through the identification of indigenous soil quality indicators used by farmers, comparing farmers' classified soil quality status to scientific measurements, the perception of farmers on the effect of Climate Change variation on soil quality while assessing some farm yield management practises.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study was undertaken within the Ada-West District in the Greater Accra region of Ghana (Figure 3.1). The Ada-west district is found along the south-eastern coast of Ghana and stretches from Akplabanya to Goi. The district is approximately 80 km to the east of the capital city, Accra and it covers an area of about 323.721km^2 . It is bounded to the North by the North Tongu District, to the East by the Ada East District, to the South by the Atlantic Ocean, District and to the west by the Ningo Prampram District.

The area generally has a gentle relief, undulating and a low-lying area with elevation not exceeding 60 meters (200 ft.) above sea level. The key relief features include the Anyamam boulders which are scattered irregularly over the sea rising from about 240 meters (800 ft.) above sea level.

Most parts of the district is characterized by coastal savannah vegetation made up of shrub and grassland supporting a viable livestock rearing in the area.

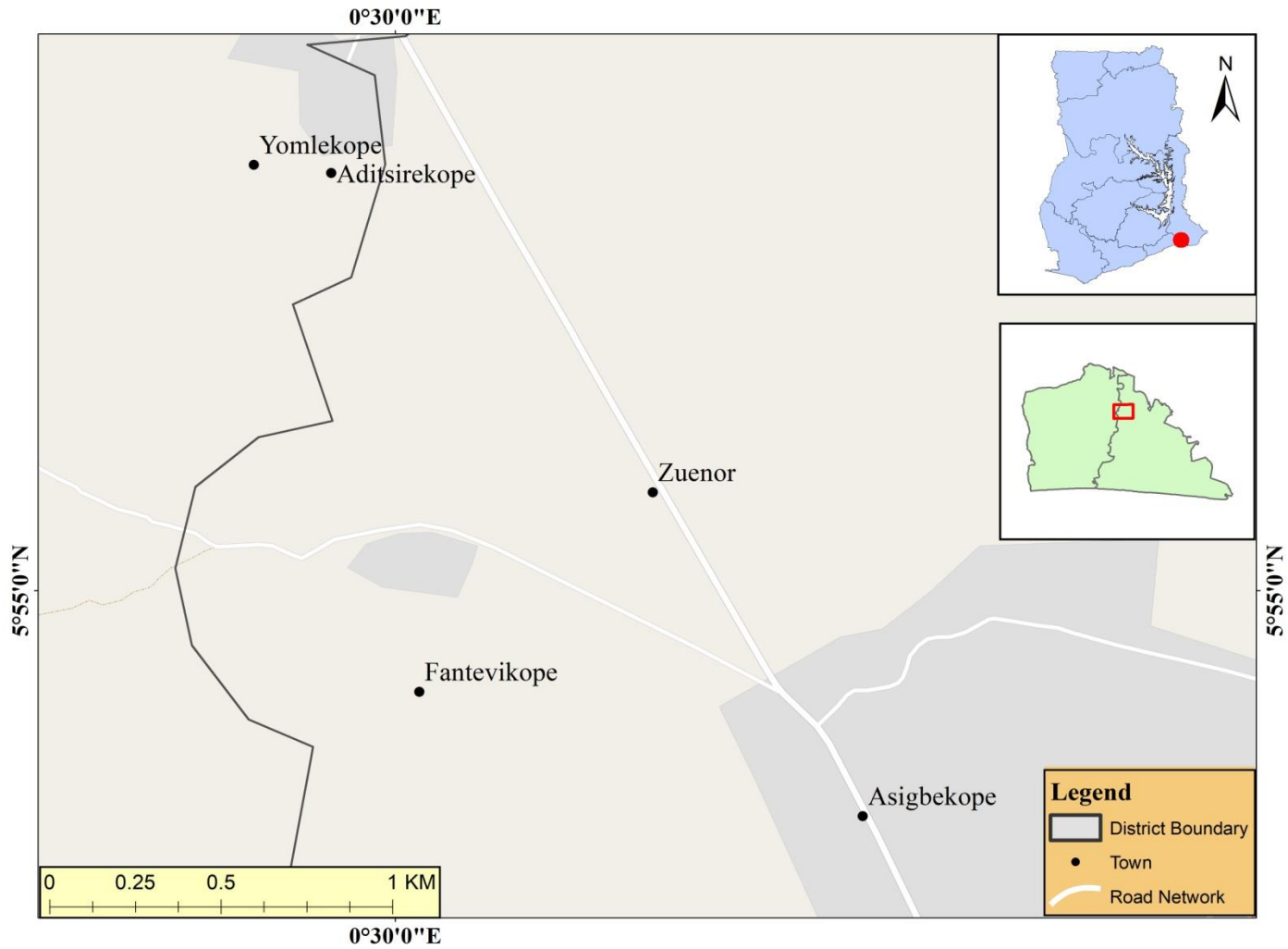


Fig 3.1 Study area map

The Ada West District experiences high temperatures throughout the year, ranging between 23°C and 33°C (GSS, 2014), making it one of the hottest parts of the country. Rainfall is generally heavy during the major season that is usually between March and September each year (GSS, 2014). The average rainfall is about 750 millimetres. The area is however very dry during the harmattan season. Humidity is usually about 60%, due to its proximity to the sea, the Volta River and other water bodies. The daily evaporation rates of the area range from 5.4 - 6.8 millimetres (GSS, 2014).

The drainage pattern of the Ada West district can generally be described as dendritic with some of the streams serving as tributaries for the Volta River. Water bodies such as Anyamam, Akplabanya, and Ada, among others spring up with increased and decreased capacities in the wet and dry seasons respectively.

Soils around the tributaries of the Volta River are mostly waterlogged and salty (GSS, 2014). The study area falls within the Ada series which is Gleyic solonetz type of soil which has a natric B horizon showing hydromorphic properties within 50 cm of the surface (FAO, 1974)

The Ada-West District has a rural setting which is mainly inhabited by the Ga-Dangme people. As at 2010, the population was about 59,124. The major occupations in the district are farming, fishing, livestock rearing (cattle) and salt mining.

According to the Ghana Statistical Service 2010 census report, the district is predominantly an agricultural one, with about 57.5 % (6,689) of households in the district engaged in agricultural activities, making farming a major economic activity. The majority of about 48% are engaged in crop farming while the remaining are into livestock and fish farming.

Crops cultivated in the area include cassava, cereals like maize, sorghum. Fruits and vegetables also cultivated in the study area include tomatoes, onions, shallots, garden eggs, pepper, carrots, okra, water melon and mango.

Five farming communities within the Ada-West district were visited; these communities were Yomlekope, Aditsirekope, Zuenor, Fantevikope and Asigbeykope, where the study farmers' perception of soil quality indicators was undertaken.

3.2 Study Design

Descriptive Study method was used in this research. This was in order to bring the researcher into contact with the actual situation on the ground in order to prevent the use of assumptions in identifying the perception of the farmers on soil quality indicators.

3.3 Sources of data

Both primary and secondary data were used in this study. With the primary source, questionnaires were administered to farmers within the study area on their perception of soil quality indicators. Soil samples were also taken and analysed at the laboratory using standard methods. The secondary source of information included literature from books, peer-reviewed journals as well as the review of both published and unpublished articles.

3.4 Social survey

A social survey was conducted using questionnaires and focus group discussion with farmers within the Ada-West district to identify indigenous soil quality indicators used by farmers, farmers' perception on the effect of climate change on soil quality and also farm management practices farmers employed to ensure or maintain good soil quality. Focus group discussions were employed in the classification of the soils into different quality

categories (High, medium and low). The social survey was conducted within the months of April and May, 2018.

3.4.1 Sample Size

In order to get a representation of the farmers within the area, the study used a sample size of 212 respondents which was obtained using the formula below.

$$\text{Sample Size} = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1 + \left(\frac{z^2 \times p(1-p)}{e^2 N}\right)}$$

Where; Population Size = N Margin of error = e z -score = z e is percentage, put into decimal form (for example, 5% = 0.05).

$$Z=1.44 \quad N=59,124 \quad e= 0.05$$

$$\cong 212$$

3.5 Assessment of soil parameters

3.5.1 Soil sampling method

A representation of the farmers (5 farmers for each soil category) were selected randomly from the responding farmers to identify soils on the field which they classified as being of high, medium or low quality. at 0-20cm depth (which is surface soil) and emptied into re-sealable plastic bags which were conveyed to the Ecological Laboratory of the University of Ghana for analysis. A total of 36 soil samples were collected which was made up of 12

samples for each soil classification (high, medium and low). This was replicated in four of the communities under study.

3.5.2 Soil sample preparation

All debris, plant residues, gravels and stones were removed from the soil samples; these were air-dried at room temperature at the Ecological Laboratory of the University of Ghana. They were then disaggregated using porcelain pestle and mortar and passed through a 2mm sieve to obtain the fine earth fraction which was then used for the various physicochemical soil parameters at the Laboratory.

Physicochemical parameters of the soils were analysed to determine the physical and chemical quality of the soils. Parameters determined include the pH, Electrical conductivity (EC), Total Nitrogen (N), available Phosphorous (P), Cation Exchange capacity (Mg, Na, Ca, K), soil particle size distribution as well as the organic carbon/organic matter content of the soils. These analyses were done to determine the quality of the soils which was then used to confirm the farmers' perception of the quality of their soils.

3.5.3 Soil pH determination

The pH of the fine earth fraction of each air-dried soil sample was determined using a 1:1 soil to distilled water ratio with a microprocessor pH meter. For each sample, 10 g of soil was weighed into a 50 ml polythene beaker and 10 ml of distilled water added. The soil-distilled water mixture was stirred vigorously with a magnetic stirrer for 30 minutes and allowed to stand for one hour for the suspended soil particles to settle. The pH meter with standard buffer solution of pH 4.0 and pH 7.0 was calibrated after which the electrode was then inserted into the supernatant (the upper part) of the soil solution. Soil pH values were

then recorded. The test was duplicated for each sample and the means taken. Readings were recorded after stabilization. The stabilization state was determined when the signal became steady after 2 minutes. The electrode was rinsed with distilled water after each sample measurement before being used for other measurements.

3.5.4 Soil Electrical Conductivity

Soil electrical conductivity was determined for the soil samples at a soil to water ratio of 1:1 using EC meter. For each sample, 10 g of soil was weighed into a 50 ml polythene beaker and 10 ml of distilled water added. The soil-distilled water mixture was stirred vigorously with a magnetic stirrer for 30 minutes and allowed to stand for one hour for the suspended soil particles to settle. Using 0.1M KCl solution the electrometer was standardized. The EC of the soil samples were then measured by inserting the standardized electrode into the supernatant (the upper part) of the soil-distilled water mixture. The EC values were then recorded. The electrode was rinsed with distilled water after each sample measurement before being used for other measurements

3.5.5 Soil particle size distribution

The Bouyoucos Hydrometer method modified by Day (1965), was used to determine the particle size distribution of the soil. Forty (40) grams of the air-dried and sieved soil sample was weighed into a plastic bottle and 100 ml of 5% Sodium hexametaphosphate ($\text{NaPO}_3)_6$ solution was added. The content of the bottle was then shaken on a mechanical shaker for 2 hours after which it was transferred into a 1.0 litre measuring cylinder and topped up to the 1.0 litre mark with distilled water. The suspension was then agitated with a plunger and five minutes later, the density of the suspension (silt and clay) was taken using a hydrometer. The hydrometer reading of the suspension was taken again after five hours

(Clay & Robinson, 1838). The contents of the cylinder after the fifth-hour reading were emptied onto a 47- μm sieve and effluent discarded. The sand retained on the sieve was then washed off into a moisture can and dried at 105 °C for 24 hours, after which the dry weight of the sand, was recorded (Day, 1965; FAO, 1974). Blank hydrometer readings were also taken. The particle size distribution was then determined using the formulae below:

$$\% \text{ clay} = \frac{\text{hydrometer reading at 5 hrs}}{40 \text{ g}} \times 100 \quad [3.1]$$

$$\% \text{ silt} = \frac{\text{hydrometer reading at 5 min} - \text{hydrometer reading at 5hrs}}{40 \text{ g}} \times 100 \quad [3.2]$$

$$\% \text{ sand} = \frac{\text{weight of oven dried sample}}{40 \text{ g}} \times 100 \quad [3.3]$$

Where 40 = weight of soil sample in grams

With the percentages of sand, silt and clay, each soil sample was given a textural class using the United States Department of Agriculture (USDA) textural triangle. Average proportions of the soil types in each soil core were determined and the corresponding average textural class was determined.

3.5.6 Soil organic carbon

The organic carbon content of the soil was determined using the wet combustion method of Walkley and Black (1934). 0.5g of soil was sieved and measured into 250ml titration flask after which 10ml of 0.167 M potassium dichromate ($K_2Cr_2O_7$) solution and 20 ml of concentrated sulphuric acid (H_2SO_4) were added to it. The flask was then swirled to ensure full contact of the soil with the solution after which the mixture was allowed to stand for 30 minutes. The unreduced $K_2Cr_2O_7$ remaining in solution after the oxidation of the oxidizable organic material in the soil sample was titrated with 0.2 M ferrous ammonium sulphate solution after adding 10ml of orthophosphoric acid and 2ml of barium diphenylamine sulphonate indicator from a dirty brown colour to a bright green end point. A standardization titration of the $K_2Cr_2O_7$ with the ferrous ammonium sulphate was done and the amount of oxidizable organic carbon was then calculated by subtracting the moles of unreduced $K_2Cr_2O_7$ from that of $K_2Cr_2O_7$ present in the standardized titration. The titre value was used to calculate the percent carbon (% C) as:

$$\% C = \frac{0.3 \times (10 - TN) \times 1.33}{W} \times 100 \quad [3.4]$$

Where %OC = Percent organic carbon

T = Titre value of the ferrous ammonium sulphate

N = Molar mass of the ferrous ammonium sulphate (0.2M)

W = The weight of the soil sample.

$$0.3 = 0.003 \times 100$$

0.003 = Milliequivalent weight of carbon (g)

1.33= correction factor (*f*)

The % Organic C was then converted to organic matter using the equation:

$$\% \text{ Organic Matter (OM)} = \% \text{ Organic carbon} \times 1.724. \quad [3.5]$$

3.5.7 Total Nitrogen

The Kjeldahl (1883) method was used in the determination of total nitrogen. One (1) gram of soil was weighed into a Kjeldahl flask and a tablet of a digestion accelerator (selenium catalyst) was added. This was followed by the addition of 5ml of concentrated H₂SO₄. The mixture was digested until the digest became clear. The test tube was then cooled and its content transferred into a 100 ml volumetric flask. Distilled water was added to the digest in the volumetric flask to the 100 ml mark. An aliquot of 5 ml of the digest was taken into a Markham distillation apparatus and 10 ml of 40 % NaOH was added and the mixture distilled. The distillate (liberated ammonia) was collected in 5 ml of 2 % boric acid (H₃BO₃). Three drops of a mixed indicator containing methylene blue and methyl red were added to the solution and then back titrated with 0.01 M HCl from green to reddish end point. The percent N was calculated as follows:

$$\% \text{ N} = \frac{0.01 \times \text{titre value} \times 0.014 \times \text{volume of extract}}{\text{Sample weight (g)} \times \text{volume of aliquot (mL)}} \times 100 \quad [3.6]$$

Where; 0.01 = Molarity of HCl, and 0.014 = Milliequivalent of Nitrogen

3.5.8 Available phosphorus

The available phosphorus in soil samples was determined using 1 M ammonium fluoride (NH₄F) standard solution, potassium hydroxide, sulphuric acid and hydrochloric acid (Bray and Kurtz, 1945). A 0.1 g of soil sample was weighed and put into a centrifuge bottle

and 50 ml of Bray 1 solution (0.03N NH₄F + 0.025N HCL) was added. The mechanical shaker was used to mix the suspension by shaking for 5 mins and left to settle overnight. The suspension was then filtered into a 100 ml volumetric flask and made up to the volume. The available phosphorus in the filtrate was determined using the molybdate-ascorbic acid method. Five ml of the aliquot was taken into a 50 ml volumetric flask and the pH was adjusted by adding P-nitrophenol indicator and drops of 4M NH₄OH until the colour changed to yellow. Then 40 ml of distilled water was added to dilute the solution. A solution which was made from a mixture of 12 g ammonium, 0.29 g potassium antimony tartrate, 140 ml of concentrated H₂SO₄ and 1.056 g of ascorbic acid (reagent B) was prepared. Eight millimetres of the reagent B was added to the solution and mixed thoroughly by shaking and allowed to settle for 15 minutes until the colour changed to different shades of blue depending on the P content in the samples. A blank was prepared using distilled water and 8 ml of reagent B. A Philips PU 8620 spectrophotometer was used to measure the intensity of the P content at a wavelength of 712 nm. The P content was then calculated as:

$$P \text{ (mg/kg)} = \frac{\text{spectrophotometer reading (mgL}^{-1}\text{)} \times \text{volume of extract}}{\text{volume of aliquot} \times \text{weight of soil sample}} \quad [3.7]$$

3.5.9 Extraction of Exchangeable bases (Ca, Mg, Na, K).

Ten grams of the soil samples were weighed into 100 ml extraction bottles. Hundred (100) millimetres of 1M ammonium acetate (NH₄OAc) solution buffered at pH 7.0 was added. The bottles were covered and then placed on a reciprocating shaker and shaken for 1 hr at 180 strokes per min. The soil suspension was then decanted and filtered. The filtrates were used for the determination of Ca, Mg, K and Na.

A 5 ml aliquot of each filtrate was pipetted into 50 ml volumetric flask and made up to the mark with deionised water. The Perkin Elmer atomic absorption spectrometer (A Analyst 800) was calibrated with the appropriate standards for Ca, Mg and Na respectively and the absorbance for each element in the filtrate determined. Exchangeable bases were calculated as:

$$\text{Ca (cmol}_c\text{kg}^{-1}) = \frac{R \times V \times E}{W \times 40} \quad [3.8]$$

$$\text{Mg (cmol}_c\text{kg}^{-1}) = \frac{R \times V \times E}{W \times 24} \quad [3.9]$$

$$\text{Na (cmol}_c\text{kg}^{-1}) = \frac{R \times V \times E}{W \times 23} \quad [3.10]$$

Where

R = AAS (Atomic absorption spectroscopy) reading in mg L⁻¹

E = Charge of cation

40 = Atomic mass of Ca and 24 = Atomic mass of Mg

23 = Atomic weight of Na

The K content in the diluted soil extracts was measured with the standardized flame photometer. The flame photometer was standardized to give a 100 full scale deflection at 10 mg/kg of K. The values obtained were then used to calculate the amount of potassium contained in the soils as shown in the formula below:

$$\text{K (cmol}_c\text{kg}^{-1}) = \frac{R \times V \times 100}{\text{Weight of soil} \times 39.1} \quad [3.11]$$

Where,

R is the flame photometer reading (ppm)

39.1 = Atomic weight of K

E = Charge of K

3.6 Data analysis

Statistical Package for Social Sciences (SPSS) software version 23.0 and Microsoft Excel (2007). was used to process the data collected. A general descriptive statistics was done for all the data collected (frequencies, percentages, mean, minimum and maximum values) and also practically representing the information in order to give a pictorial view of the situation, bar graphs and pie charts.

Cross tabulation was also employed in analysing the questionnaires to generate the Pearson co-efficient which was used to determine the associations between demographic data and variables after which logistic regression analysis was done on variables which showed significant associations. A binary logistic regression was used to examine demographic factors and their influence on the perception that climate change had an effect on soil quality

The physical and chemical parameters of the soil samples collected were subjected to a One-way Analysis of variance test which was conducted to analyse results for inference and conclusion. Significant means obtained were separated by the LSD approach at 5% significance level ($P \leq 0.05$). Factor analysis was done using the Principal Component Analysis (PCA) to determine factors with high loadings.

CHAPTER FOUR

RESULTS

4.1 Demographic Characteristics of Respondents

Table 4.1 below summarises the demographic characteristics of respondents. A total of 212 questionnaires were administered and all were filled and returned giving a response rate of 100%. This consisted of 99 (46.7%) males and 113 (53.3%) females. A greater percentage of the respondents were aged above 45 years (34.5%) with the least being below 15 years (0.5%).

Most of the respondents were married, representing 66% of the total respondents, with 18.4% being single while the rest had been previously married (divorced, widowed or separated).

Majority of the respondents had basic education (51.4%) whilst those with no formal education and those with tertiary education formed 34.9% and 2.9% respectively. With respect to religion, 88.2% were of Christian faith while the traditionalists formed 7.6%, Moslems 1.4% and others being 2.8%.

With respect to years of farming experience, 37.8% of the respondents had farmed for over 20 years, those with 11-15 years of farming experience formed 11.8%, whilst 12.7% had farmed for less than 5 years.

Table 4.1 Demographic characteristics (n=212)

Variables	Frequency (F)	Percentage (%)
Gender		
Male	99	46.7
Female	113	53.3
Age		
Below 15yrs	1	0.5
15-24yrs	34	16.0
25-34yrs	59	27.8
34-45yrs	45	21.2
45yrs & above	73	34.5
Marital Status		
Single	39	18.4
Married	140	66.0
Divorced	8	3.8
Seperated	4	1.9
Widowed	21	9.93
Education		
No Formal Education	74	34.9
Basic	109	51.4
Secondary	23	10.8
Tertiary	6	2.9
Religion		
Christian	187	88.2
Islamic	3	1.4
Traditional	16	7.6
others	6	2.8
Number of years Farmed		
Less than 5 years	27	12.7
5-10years	57	26.9
11-15years	25	11.8
16-20years	23	10.8
Over 20 years	80	37.8

Where n= sample size

4.2 Identification of Indigenous Soil Quality Indicators Used by Farmers

Figure 4.1 below shows the percentages of farmers' perception on the type of soils their farms. All the farmers asserted that they were able to identify the type of soils on their farmlands. Majority of the farmers described their soils to be sandy (61.8%), followed by Loamy soil (20.3%), clayey (11.8), both sandy and loam (5.7%) and silt (0.5%).

Only 0.5% of the respondents tested their soils scientifically, the remaining 99.5% used indigenous soil quality indicators in deciding on the quality of their soils.

Figure 4.2 shows the percentages of respondents who use the individual soil quality indicators. The most frequently used soil quality indicators by farmers were the presence of some plants and weeds, crop yield and plant growth and development representing 71.6%, 96.2% and 98.1% respectively. The least used soil quality indicators by farmers were thickness of topsoil (22.6%) and soil erosion (36.8%), whilst soil moisture content (69.3%), soil colour (56.1%), texture of the soil (47.6%) and the presence of some soil living organisms (44.8%) were also moderately used.

Farmers who used the presence of some plants and weeds as an indicator of soil quality described the vigorous growth of these weeds as a sign of good soil quality while patched growth meant there was something lacking in the soil. All the listed weeds in table 4.2 were perceived to be indicators of good soil quality except the nut grass whose initial presence was an indication of good soil moisture but gradually drained the soil of its moisture.

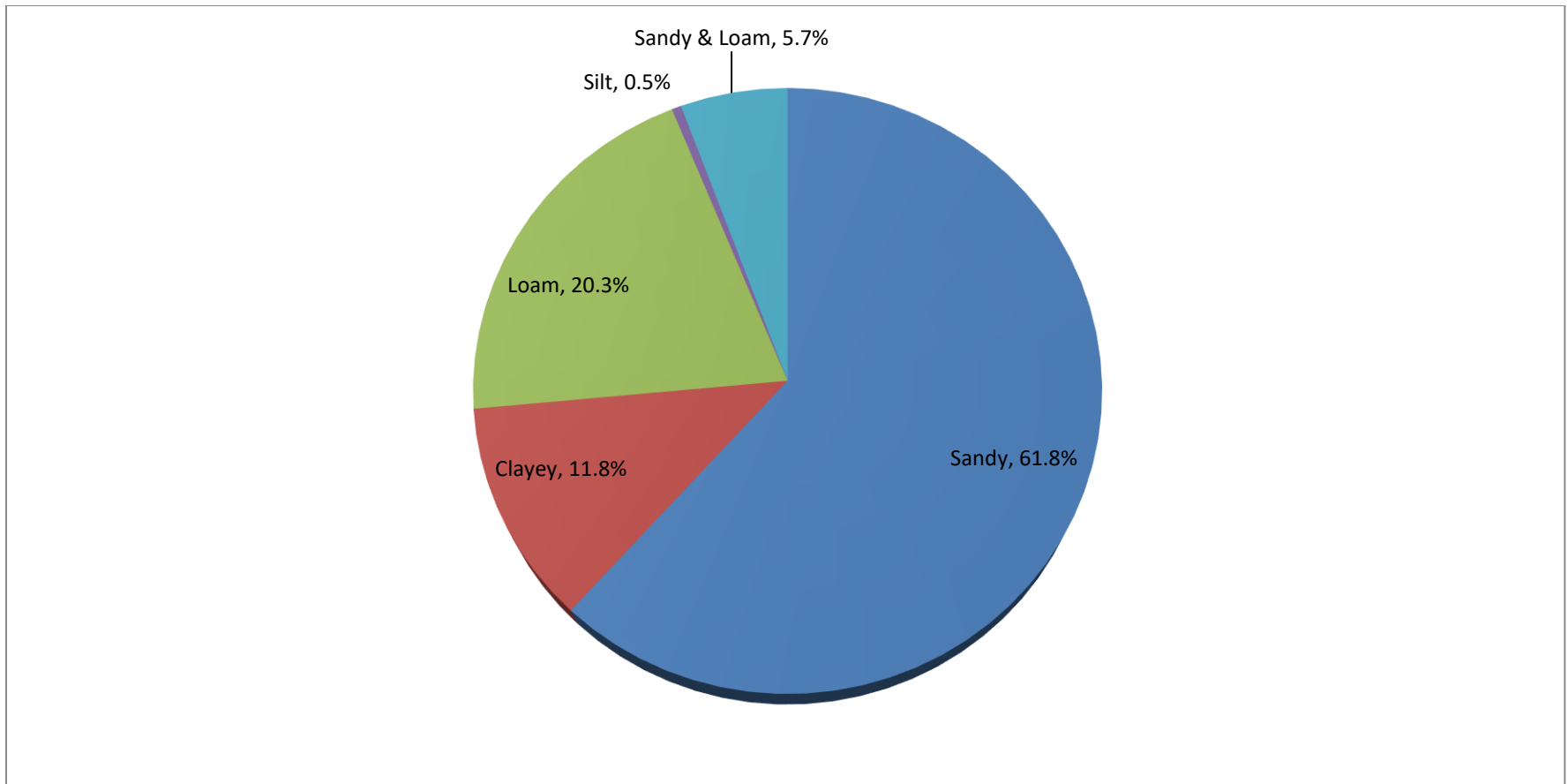


Fig. 4.1 Percentages of perceived soil type

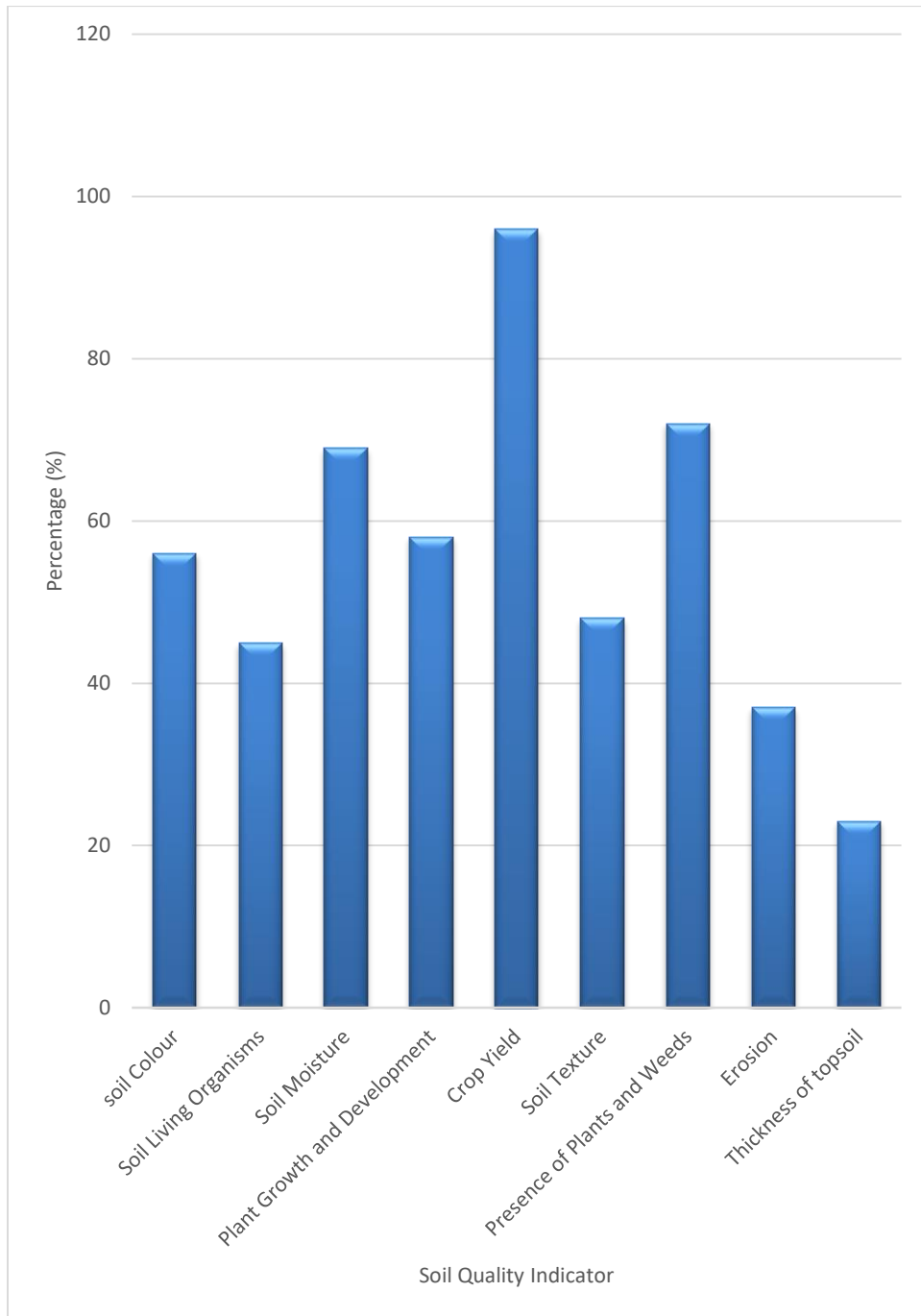


Fig 4.2 Number of farmers who use the individual soil quality indicators to determine soil quality



Fie nga/nutgrass (*Cyperus rotundus*)



Bodetso/Neemtree (*Azadirachta indica*)



Gla Elephant grass
(*Pennisetum purpureum*)



Tolile/Crabgrass (*Digitaria Sanguinalis*)

Plate 1: Plants and weeds used as Soil Quality Indicators

Table 4.2 Plants and weeds used as soil quality indicators

Common name	Local Name	Scientific Name
Guinea grass	Go nga	<i>Panicum maximum(megathyrus maximus)</i>
Nut grass	Fie nga	<i>cyperus rotundus</i>
Neemtree	Bodetso	<i>Azadirachta indica</i>
Elephant grass	Gla	<i>Pennisetum purpureum</i>
Crabgrass	Tolile	<i>Digitaria Sanguinalis</i>
	Zue	<i>Panicum minimum</i>

According to the farmers, the most important soil quality indicator to them was crop yield (45.3%) followed by plant growth and development (24.5%), whilst the least important soil quality indicators were soil erosion (0.5%) and soil texture (0.5%), whereas 0.5% asserted that they did not see any of the soil quality indicators as being the most important. This is shown in Table 4.3 below

Table 4.3 Most important soil quality indicator to farmers

Indicator	Frequency (f)	Percent (%)
None	1	0.5
Soil Colour	23	10.8
Soil living organisms	1	0.5
Soil moisture	15	7.1
Plant growth & development	52	24.5
Crop yield	96	45.3
Soil Texture	1	0.5
Plants & weeds	22	10.4
Erosion	1	0.5
Total	212	100.0

4.2.1 Association between soil quality indicators and demographic data

Tables 4.4a and 4.4b summarises the association between soil quality indicators and demographic data.

A bivariate analysis conducted to determine the association between soil quality indicators and demographic data showed that marital status was significantly associated with the use of the presence of some plants, weeds and soil living organisms as indicators of soil quality ($p \leq 0.05$).

In this analysis, farmers who had attained basic, secondary and tertiary education were classified as having some formal education. The educational status was found to be significantly associated with the use of some plants and weeds as indicators ($p \leq 0.05$). The duration of farming was associated with the following soil quality indicators: soil moisture, soil texture, presence of some plants and weeds and soil erosion ($p \leq 0.05$). The gender of a farmer influenced the use soil living organisms as an indicator. All other soil indicator variables, apart from those mentioned above were however not influenced by demographic characteristics ($p > 0.05$).

Table 4.4a Showing Association between demographic Characteristics and soil quality indicators

Indicators:	Soil Colour			Soil Living Organisms			Soil moisture			Plant Growth & Development			Crop yield		
	f	X ²	Pvalue	f	X ²	Pvalue	f	x ²	P value	f	x ²	P value	f	x ²	P value
Gender		3.18	0.07		5.72	0.02*		0.24	0.62		0.77	0.38		0.44	0.51
Male	62			53			67			98			97		
Female	57			42			80			110			109		
Age(yrs)		2.10	0.55		1.22	0.75		7.23	0.07		0.26	0.97		1.22	0.75
<15	1			0			1			1			1		
15-24	17			17			27			33			34		
25-34	31			26			46			58			57		
>34	70			52			73			116			114		
Marital Status		0.57	0.45		3.88	0.05*		0.57	0.45		0.92	0.34		1.40	0.24
Single	24			23			29			39			39		
Married	95			72			118			169			167		
Education		0.54	0.46		0.01	0.96		0.17	0.68		0.18	0.68		0.01	0.94
No Formal Education	39			33			50			73			72		
Some formal education	80			62			97			135			134		
Years Farmed		0.27	0.87		2.89	0.24		6.84	0.03*		1.41	0.5		0.36	0.84
< 5	14			8			19			27			26		
5-10	33			27			47			55			56		
>10	56			60			81			126			124		

Note: figures in brackets are %. P values with * are significantly associated, f= frequency of users of specific indicators.

Table 4.4b Showing Association between soil quality indicators and demographic data

Indicators:	Soil Texture			Plants and weeds			Thickness of Topsoil			Soil Erosion		
Variables	F	χ^2	P value	f	χ^2	P value	f	χ^2	P value	f	χ^2	P value
Gender		0.36	0.55		3.38	0.07		0.63	0.43		0.03	0.87
Male	45			77			20			37		
Female	56			75			28			1		
Age(yrs)		2.38	0.5		3.65	0.30		1.73	0.63		2.41	0.49
<15	1			0			0			0		
15-24	19			27			10			16		
25-34	28			42			11			20		
>34	53			83			27			42		
Marital Status		0.02	0.88		3.93	0.05*		0.60	0.44		0.75	0.39
Single	19			33			7			12		
Married	82			119			41			66		
Education		1.17	0.28		6.64	0.01*		0.01	0.93		0.44	0.51
No Formal Education	39			45			17			25		
Some formal Education	62			107			31			53		
Years Farmed(yrs)		3.07	0.04*		4.85	0.04*		0.13	0.94		3.84	0.032
<5	15			18			6			11		
5-10	25			43			12			16		
>10	61			91			12			51		

Note: figures in brackets are %. P values with * are significantly associated, f= frequency of users of specific indicators.

4.3 Assessment of farmer based soil quality status

Using focus group discussions, farmers categorised their soils into high, medium and low quality. Soils that were perceived to be of high quality were described to have high water holding capacity, supported vigorous growth of plants and weeds as well as high crop yield. Meanwhile, soils farmers' classified to be of medium quality were described as soils which were neither of high quality nor low quality but rather exhibited an intermediary characteristic. According to them these soils are able to hold some amount of water but plants do not do so well as compared to those of high quality. Soils considered to be of low quality were described as easily losing their soil water content, experiencing low yield as well as being characterised by the yellowing of leaves of crops and weeds.

During the focus group discussion soil colour was only used as an indicator in areas with black soils. According to the farmers, 'the darker the soil colour, the higher the potential it being of a higher quality.

4.3.1 Assessment of the quality of soils using physical soil indicators

Table 4.5 shows the particle size distribution of the soil samples. Soils within the perceived high quality category were found to contain a mean of 88% sand, 7% silt and 5% clay. Those within the perceived medium soil quality category also had mean values of 88% sand, 8% silt and 4% clay content whereas those within the perceived low soil quality category recorded mean values of 89% sand, 7% silt and 4% clay.

From the percentages of soil particle size distribution recorded it was observed that the soils generally had high sand content.

Putting the mean values for the various perceived soil quality categories in the soil texture triangle, it was observed that all the soils had a sandy texture.

It was also observed that there was no significant difference between the means of the sand, silt and clay particles within the various farmers' soil quality classification.

Table 4.5: Soil particle size distribution

Soil parameters	Soil Quality Category		
	High	Medium	Low
Sand (%)	88a	88a	89a
Silt (%)	7a	8a	7a
Clay (%)	5a	4a	4a
Textural Class	Fine Sand	Fine Sand	Fine Sand

Means followed by the same letters in the same row are not significantly different at $P \geq 0.05$.

4.3.2 Chemical assessment of soil quality

The mean values of the soil chemical parameters are shown in Table 4.6 below. The lowest pH (5.8) was obtained in the low soil quality category and the highest pH (6.6) in the high soil quality category.

Conductivity was found to be high in the high quality soil category (0.047ds/m) whilst the lowest was in the low soil quality category (0.022ds/m). Available phosphate ranged from a minimum of 44.62mg/kg to a maximum of 48.68 mg/kg in the medium soil quality category and high soil quality category respectively. The least total Nitrogen was recorded in the low soil quality category (0.12%) whereas the highest was recorded in the high soil

quality category (0.13%). The least OC (0.12%) and OM (0.81%) were recorded in the low soil category whilst the highest was recorded in the high soil quality category with values 0.81% and 1.41% respectively (Table 4. 6). With respect to ions calcium and potassium recorded the highest values in the high soil quality category (2.539 cmol/kg and 0.136 cmol/kg respectively) and the least values of 1.656 cmol/kg and 0.055 cmol/kg respectively in the low soil quality category.

Table 4.6: Chemical indicators of soil quality categories

Soil parameters	Soil Quality Category		
	High	Medium	Low
pH	6.6a	6.1b	5.8b
EC (ds/m)	0.047a	0.028b	0.022b
Avail. P (mg/kg)	48.683a	44.617a	47.875a
TN (%)	0.134a	0.128a	0.124a
OC (%)	0.814a	0.657a	0.472b
OM (%)	1.403a	1.132a	0.814b
Ca (cmol/kg)	2.539a	1.857a	1.656a
Mg (cmol/kg)	0.704a	0.778a	0.441a
Na (cmol/kg)	0.034a	0.026a	0.053a
K (cmol/kg)	0.136a	0.057a	0.055a

Means followed by different letters in the same row are significantly different at $P \leq 0.05$.

EC, electrical conductivity; OC: organic carbon. TN: total nitrogen

4.3.3 Synthesis of soil quality difference based on soil attributes

It was observed from the determined chemical indicators that apart from available Phosphorous which recorded larger values in soil farmers' classified as low soil quality category as compared to the medium soil quality category, the remaining measured parameters showed an increasing trend from low to high.

The pH of the soil ranged from moderately acidic to neutral (Table 4.6). Inferring from table 2.1, exchangeable cations (Ca, Mg, Na, and K), EC, OC and Total nitrogen in the soils fell within the low category. Whereas the OM content of the soil ranged from low to moderate none of the soil samples fell within the standard high category. The Available Phosphorus for all the soils was within the moderate range.

Analysis of variance conducted on the determined parameters showed that the pH, EC, OC and OM differed significantly among the soil quality categories (high, medium and low) at 95% confidence level ($P \leq 0.05$). However, Available phosphorous, sodium, magnesium and potassium, sand, silt and clay did not differ significantly ($P > 0.05$).

4.3.4 Soil variability using Principal Component Analysis

In order to reduce the dimensions of the soil quality attributes and to understand which variables best explains the variation, principal component analysis (PCA) was employed with an eigen value greater than 1. Table 4.7 gives a summary of the principal component analysis. In the principal component analysis, 13 components were used whereas the first four accounted and explained 85.36% of the total variance. PC1 (first component) accounted and explained 49.91% of the total variance and this has a higher positive loading on EC (0.84), Available Phosphorus (0.93), OC (0.74), OM (0.74), Ca (0.97), and Mg (0.94) was therefore termed as Soil nutrient factor. The second component (PC2) accounted for 16.36% of the total variance and was significantly loaded on Sand (-0.74), silt (0.93) and was termed as soil texture factor. The third component (PC3) explained 11.24% of the variance in soil quality and had a high positive loading on Clay (0.97) and termed soil texture factor. The last component (PC4) explained 7.86% and had a high negative loading on Sodium (-0.88) and was therefore termed as Sodium factor. All other variables which had a factor loading or scores below ± 0.7 were observed as not significant.

The communalities of the soil attributes in this study imply that the four components derived explain about 50% to 90% of the variance of the soil attributes. The OC, OM, Mg, K, Sand, silt, Clay, Available P and EC contributed more than 80% each of the total variance in the soil quality categories

Table 4.7: Factor loadings of soil physicochemical parameter

Soil quality attribute	Principal component, PC ^{a,b,c}				Communalities
pH	0.626	0.345	0.161	0.269	0.609
Electrical Conductivity	0.840	0.033	0.35	0.22	0.877
Available Phosphorus	0.930	0.135	-0.146	-0.092	0.913
Total Nitrogen (TN)	0.462	-0.539	0.189	0.186	0.574
Organic Carbon (OC)	0.741	-0.137	0.144	0.566	0.909
Organic Matter (OM)	0.741	-0.137	0.144	0.566	0.909
Calcium Ca	0.967	0.063	0.062	0.063	0.948
Magnesium	0.937	-0.043	-0.127	0.011	0.897
Sodium (Na)	0.026	0.079	0.094	-0.882	0.794
Potassium (K)	0.879	0.151	0.198	0.098	0.845
Sand	-0.198	-0.742	-0.597	0.073	0.951
Silt	0.195	0.928	-0.124	-0.057	0.918
Clay	0.038	-0.095	0.971	-0.032	0.954
Eigenvalues	6.488	2.126	1.462	1.021	n.a.
% of Variance	49.908	16.355	11.244	7.856	n.a.
Cumulative of Variance	49.908	66.263	77.506	85.362	n.a.

a. Rotation method: Varimax with Kaiser normalisation. b. Boldface factor loadings are considered highly weighted. c. PC1 is soil nutrient factor, PC2 is soil texture factor, PC3 is soil texture factor, and PC4 is Sodium factor. n.a.: not applicable

4.4 Farmers perception on the effect of climate change on soil quality

Most respondents (97.2%) asserted that they were aware that the climate was changing. The farmers indicated that, over the years they have noticed an increase in temperatures, decrease in rainfall, increase in drought condition, erratic rainfall and shortening of the raining season.

Meteorological data on the annual mean temperature and rainfall taken for a 25 year period (1988-2012) from the Ada area confirms the assertion of farmers that the climate is changing. (Figure 4.3 and 4.4). The mean annual temperature for the period ranged from 28⁰C–29⁰C while the mean annual rainfall for period ranged from the 98mm-296mm. The highest rainfall was recorded in the year 1991 which was immediately followed by the lowest annual rainfall in 1992. Whereas the highest mean annual rainfall for the period was recorded in 1998, the lowest was recorded in 1989.

It could be observed from the graphs (Fig. 4.3 and 4.4) that both mean annual temperature and rainfall was fluctuating during the period. Nevertheless the linear trend analysis shows that both mean annual temperature and rainfall has been rising during the period. With the linear trend line showing that the mean annual temperatures were rising more steadily than the mean annual rainfall. This shows that both the mean annual temperature and rainfall in the Ada area are changing, but at different rates.

Out of the number of farmers who were aware that the climate was changing, 68.4% perceived that climate change had an effect on the soil quality (figure not indicated).

With respect to the effect of climate change on their soils, 35.6% of them were of the view that it reduced the productivity of the soils, 26.5% said that it reduced the moisture content of the soil. Other effects stated were erosion of soil nutrients (9.1%), effects on the soil texture (6.1%), retarded plant growth (4.5%), soil compaction (5.3%), rapid increase in diseases (2.3%), death of crops (9.1%), delay in plant maturity (0.8%) and it also had effect on the soil living organism (0.8%). (Table 4.8).

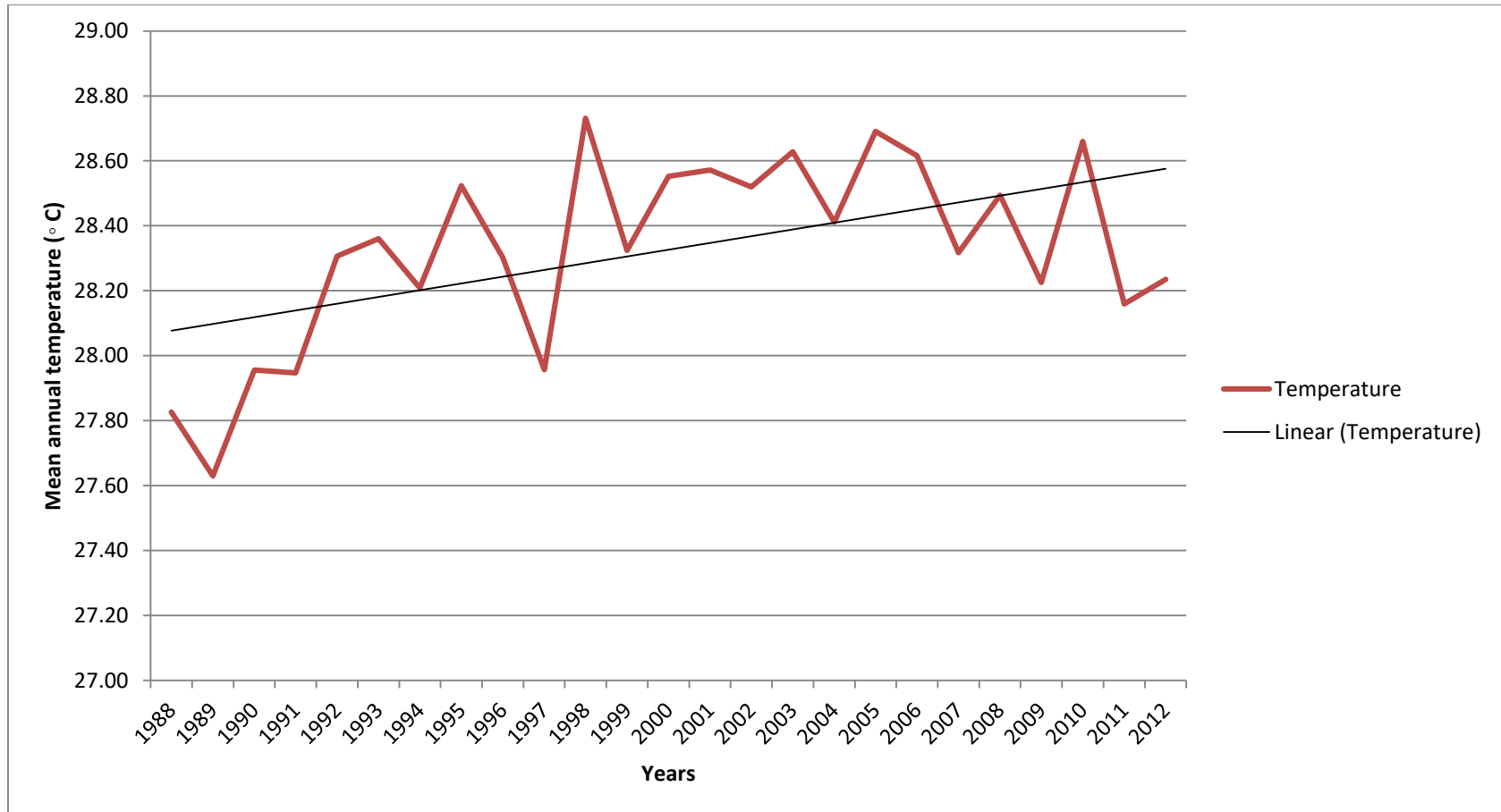


Fig.4.3 An average annual temperature from 1988-2012 of the Ada area showing an increasing trend in annual temperature

(Source: Ghana Meteorological Agency)

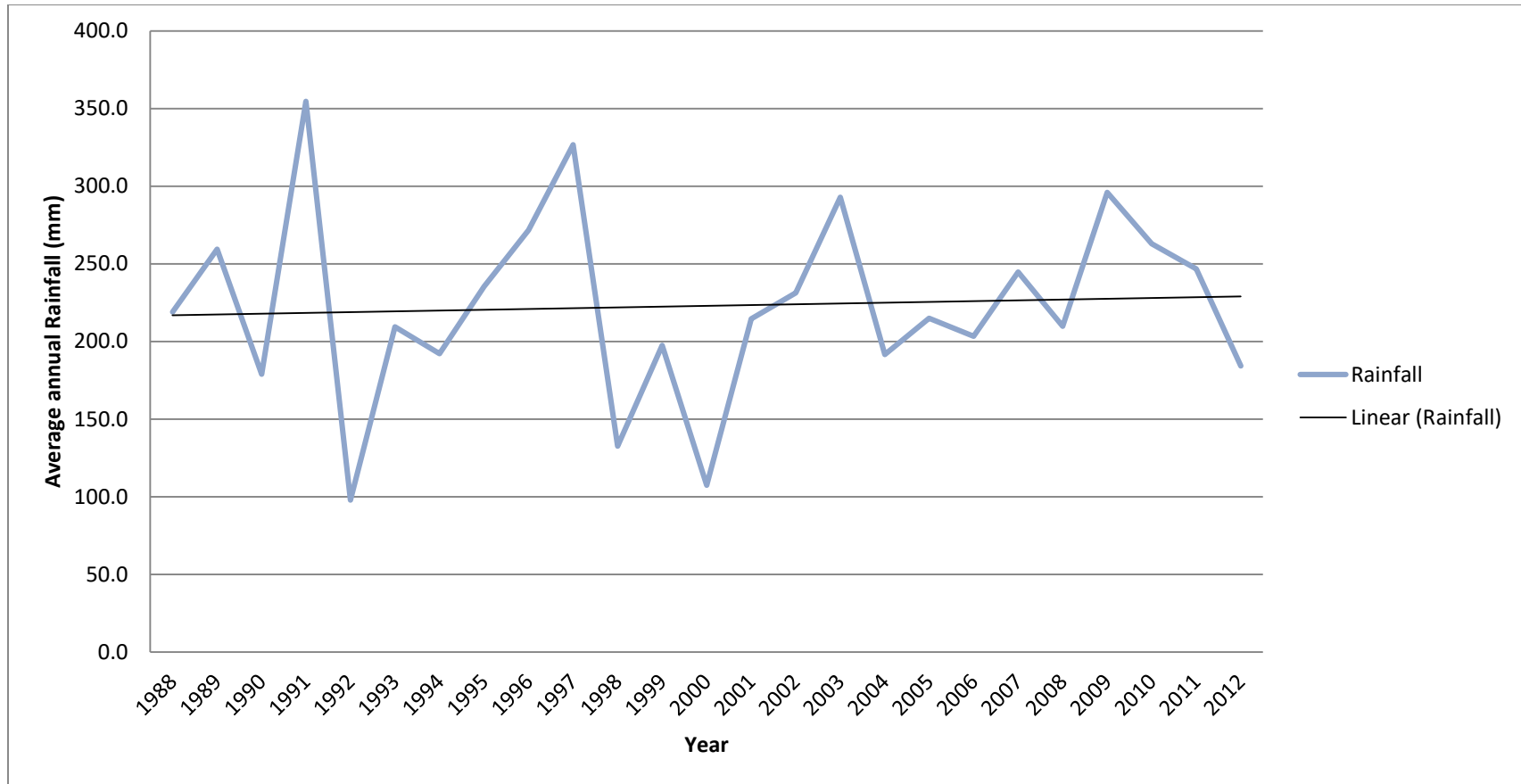


Fig.4.4 An average annual rainfall from 1988-2012 of the Ada area showing an increasing trend in annual rainfall.

(Source: Ghana Meteorological Agency)

In dealing with the effects of climate change on their soil quality, 80.8% asserted that they did nothing, (they still depended the first rains before planting), 3.5% waited for the second rain before planting, 12.8% practised irrigation farming whilst 2.8% used mulch.

Table 4.8 Perceived effects of Climate Change on soil quality

Perceived Effects	Frequency	Percentage (%)
Reduction in soil productivity	47	35.6
Affects soil moisture content	35	26.5
Erosion of soil and nutrients	12	9.1
Affects soil texture	8	6.1
Retards plant growth	6	4.5
Soil compaction	7	5.3
Rapid increase in plant disease	3	2.3
Over heated soils which lead to death of crops	12	9.1
Delay in plant maturity	1	0.8
Affects soil living organisms	1	0.8

4.4.1 Binary Regression on factors that influence farmers perception on impact of climate change on soil quality

A binary logistic regression was used to examine demographic factors and their influence on the perception that climate change had an effect on soil quality revealed that education had an influence on farmers' perception that climate change had an effect on soil quality. It was further revealed that basic education, Secondary education and Tertiary education

had an influence on people’s perception that climate change had influence on soil quality.
(Table 4.9)

Those who had acquired basic education and those who had secondary education were 27.60 and 27 times more likely to have the perception that climate change had an effect on the soil respectively, compared to those with no education. While those with tertiary education were 33.37 times more likely to have the perception that climate change had an effect on the quality of soils as compared to those with no education.

Table 4.9: Factors that influence farmers perception on climate change impact on soil quality

variables	P Value	OR	CI (95%)
gender	0.67	1.20	0.52-2.78
age	0.12		
15-24yrs	1.00		0.00
25-34yrs	0.07	0.19	0.03-1.13
34-45yrs	0.04	0.23	0.06-0.92
45yrs & above	0.78	1.18	0.37-3.75
Single	0.49	1	
Married	0.41	2.36	0.31-18.04
Divorced	0.73	0.78	0.18-3.29
Separated	0.65	1.71	0.16-18.21
Widowed	0.61	2.31	0.09-59.30
No Formal Education	0.11		
Basic	0.02*	27.60	1.68-454.71
Secondary	0.02*	27.00	1.65-441.10
Tertiary	0.02*	33.37	1.97-564.19
Less than 5 yrs experience	0.00*		
5-10years	0.13	4.39	0.64-29.99
11-15years	0.21	0.94	0.22-4.01
16-20years	0.94	1.48	0.28-7.71
Over 20 years	0.65	0.12	0.03-0.52

4.5 Soil management practises used by farmers

Out of the 212 respondents, 208 (98.1%) were able to tell when soil quality was deteriorating. Figure 4.5 gives a summary of farm management practises farmers use to increase yield. When asked what farm management practise they used to help deal with the effect of the deteriorating soil quality, most of them (91.5%) said they applied soil amendments. A few of them either moved to a different land (34.9%) or changed their seed variety (15.6%) whereas 40.1%, 50.9%, 57.1% and 61.8% either practiced mixed cropping, fallowing, change the crops they grow or practice crop rotation respectively

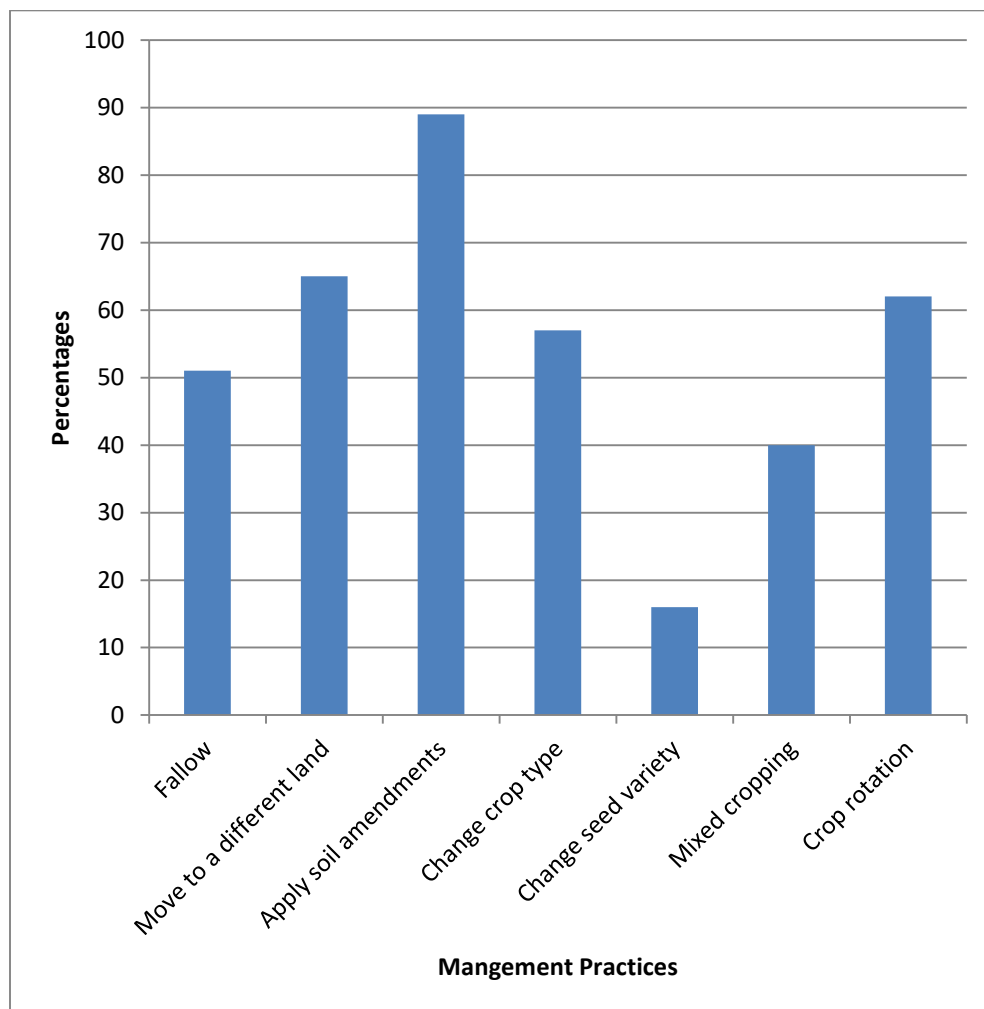


Fig. 4.5 Farm yield management practices

4.5.1 The use of soil amendments

Majority of the respondents (91.5%) used soil amendments, out of which 19.5% of them use just organic amendments, 9.3% use inorganic amendments whilst the remaining 71.1% used both organic and inorganic amendments. Figure 4.6 shows the type of soil amendments used by farmers.

Majority of the respondents however preferred the use of organic amendments (65.2%) compared to inorganic amendments (34.8%). It was enquired from the respondents, the reason for their preference of soil amendments which majority of them said their preference was based on its ability to increase crop yield rapidly (54.6%), readily available (18%), easy to use (17%), 0.5% had no reason for their choice of soil amendment, while the others gave various reasons such as; amendment did not produce weeds, retained soil nutrients and had less negative effect on the soil and the environment.

The results showed that majority of respondents (36.3%) had no idea about the specific amount of amendment to apply, 19.7% depended on their previous crop yields to determine the soil amendments to be used, 19.2% used as much as they could and 12.4% received advice from extension officers on the application of soil amendments. The remaining others (12.4%) based their application of soil amendments on the size of their lands, knowledge from experience, information from parents and personal observations (Fig 4.7)

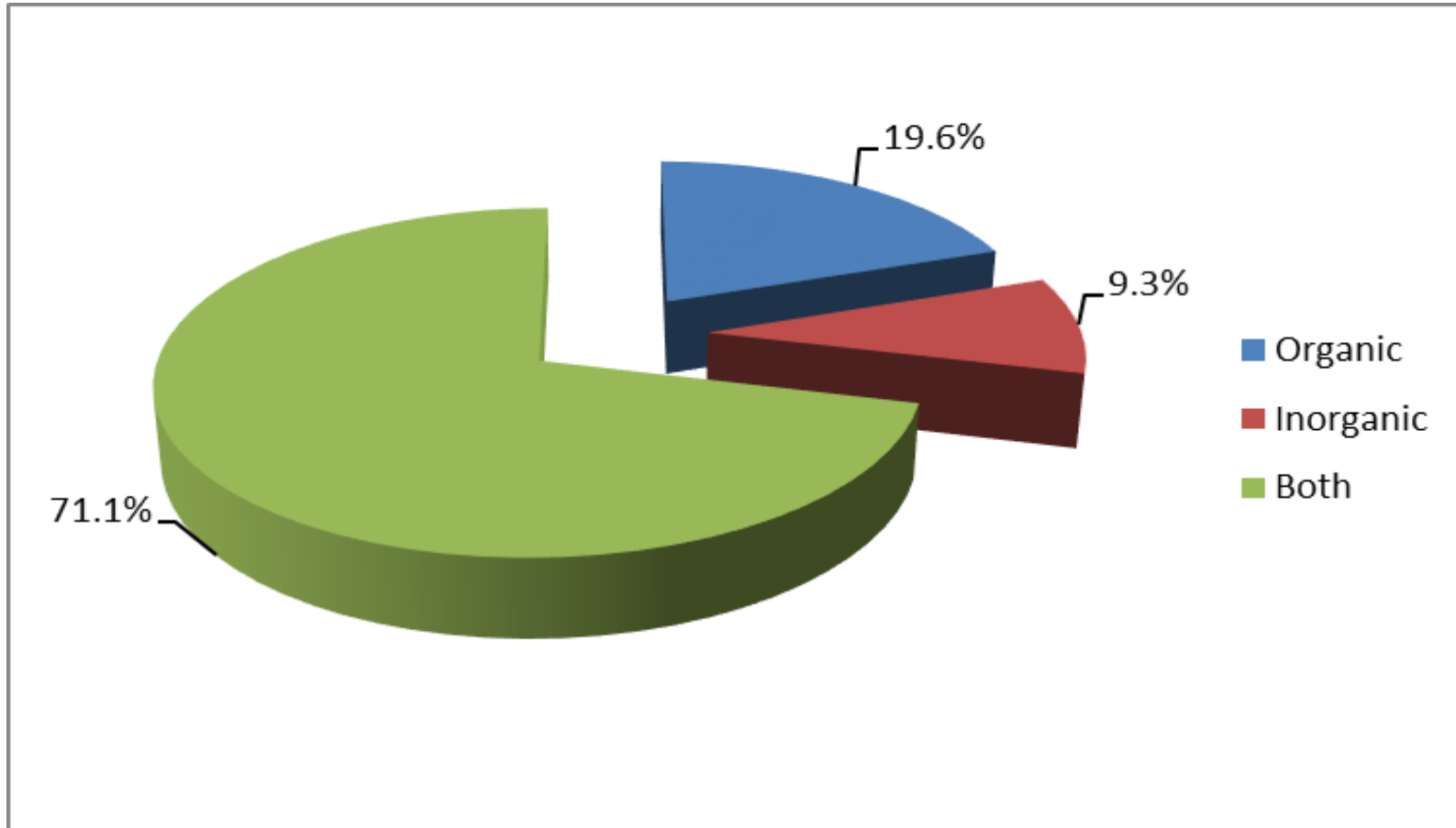


Fig. 4.6 Farmers' choice of soil amendments

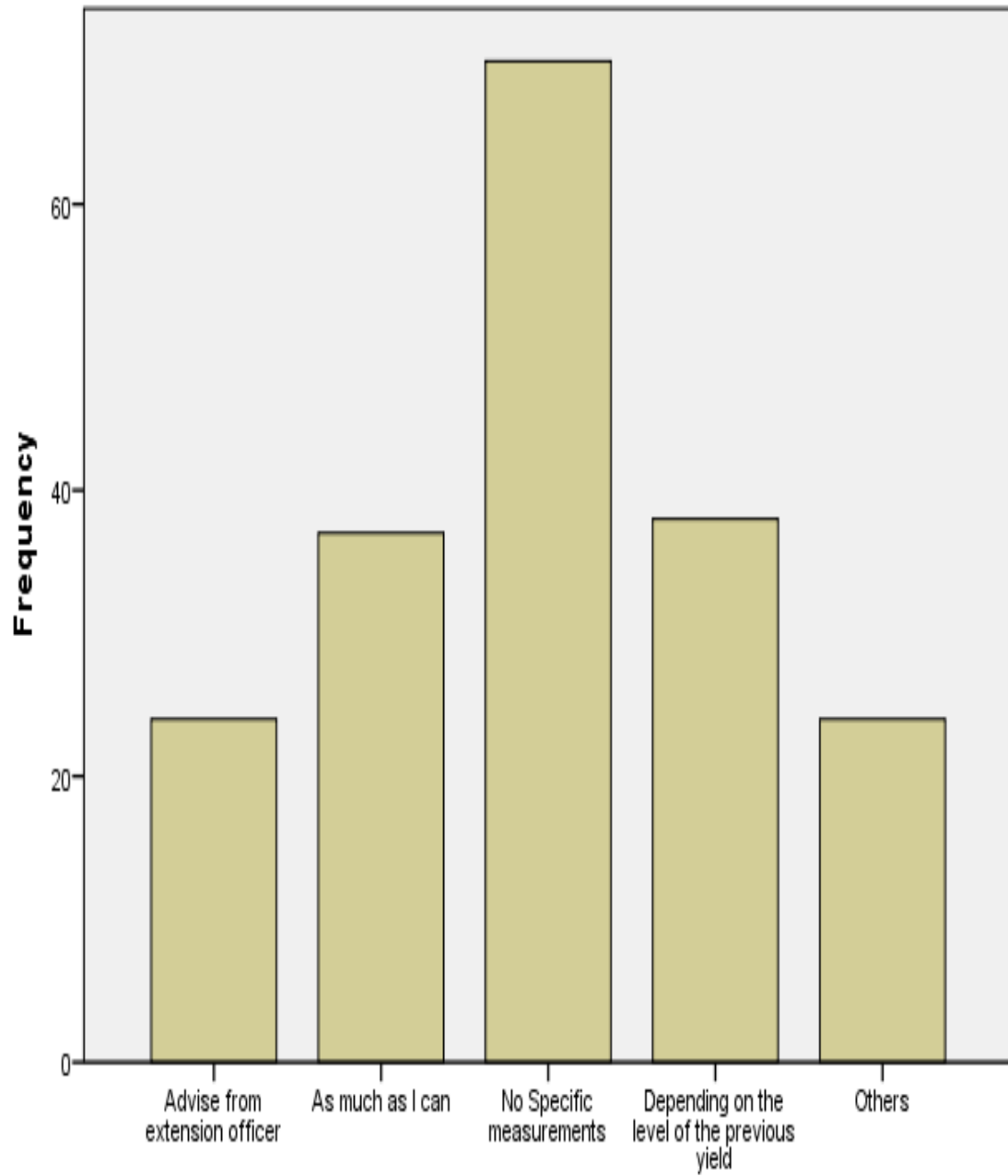


Fig.4.7 Famers source of information on soil amendments application rates

4.5.2 Association between demographic characteristics and soil amendments used

A bivariate analysis was conducted to determine the association between demographic characteristics of farmers and whether they used soil amendments. The results showed that age, marital status and years of farming experience was not significantly associated with the use of soil amendments ($p > 0.05$) whereas gender and type of crops cultivated significantly influenced the use of soil amendments by farmers ($p \leq 0.05$).

4.10 Association between demographic characteristics and the users of soil amendments

Variables	χ^2	P Value
Gender	4.73	0.03*
Age	2.02	0.73
Marital Status	3.78	0.44
Education	7.03	0.71
Number of years Farmed	6.08	0.63
Type of crops cultivated	20.23	0.00**

* shows significance, where $p \leq 0.05$.

** shows significance where $p \leq 0.01$

CHAPTER FIVE

DISCUSSION OF RESULTS

5.1 Assessment of farmer based soil quality status

Farmers basically used physical indicator to determine the quality status of the soil. The finding of this research is consistent with the findings of Dawoe *et al.* (2012) and Tesfahunen *et al.* (2011), who stated that local farmers used crop yield and performance, soil depth, colour, soil susceptibility to erosion as indicators of soil quality. They also used these criteria to classify the different category of soils into high quality, medium or low quality. These indicators they used were mostly those visible to the eye which is consistence with the findings of Tesfahunen *et al.* (2011) which showed that, local farmers ascribed importance to factors visible to the eye in determining the quality of soils.

Similar to the study by Omari *et al.* (2018), the vigorous growth of weeds was used by local farmers as an indication of good soil quality indicators whereas patched growth of weeds on soils was an indication low soil quality. The weeds used as soil quality indicator include *Panicum maximum (megathyrsus maximus)*, *cyperus rotundus*, *Azadirachta indica*, *Pennisetum purpureum* and *Digitaria Sanguinalis*. Contrary to the findings of the study conducted by Omari *et al.* (2018) where some of the plants and weeds used as soil quality indicators were indicators of low soil quality, in this study, the presence and vigorous growth of all the fore-mentioned plants and weeds was considered as an indicator of high soil quality. Farmers also indicated that the presence of nutgrass (*cyperus rotundus*) was an indication of good soil moisture but had the potential to reduce the soil moisture with time.

Unlike the findings of Dawoe *et al.* (2012) where soil colour was the most important soil quality indicator, this study revealed that crop yield and plant development was the most important soil quality indicator to the farmers of the Ada-West District. This could be attributed to the farmers realising from their farming experience that soil colour is not always a dependable indicator of soil quality but rather the previous crop yield. This is in line with the assertion that “though soil colour is easily discerned, it has little use in predicting soil characteristics, but rather it is useful in distinguishing boundaries within a soil profile and determining the origin of a soil's parent material (FAO, 1974). Soil colour can be used to indicate wetness and waterlogged conditions, and as a qualitative means of measuring organic, salt and carbonate contents of soils (FAO, 1974).

The study showed that some of the soil indicator variables had some association with the demographic characteristics.

5.2 Assessment of soil quality status using physical soil indicators

Particle size distribution conducted on soil samples revealed that the soils were mostly sandy in texture. According to Schoenholtz *et al.* (2000), soil texture is the most fundamental qualitative physical property controlling water, nutrient, and oxygen exchange, retention, and uptake, making it therefore a master soil property that influences most other properties and processes. It therefore implies that soils in this area are generally poor in nutrient reserves and have a low water holding capacity, but provide favourable conditions for root growth, soil aeration and drainage of surplus water (Roy *et al.*, 2006). Thus the generally low organic carbon and ion contents of the soils could be attributed to the texture of the soil.

5.2.1 Assessing soil quality status using chemical soil indicators

The pH of the soil ranged from moderately acidic to neutral. According to Roy *et al.* (2006), within this range of pH, most plants thrived well.

The analysis further showed that exchangeable cations (Ca, Mg, Na, and K) in the soils were generally low. It was also realised that the EC values were generally very low in all the categorised soils and hence the soils were found to be non-saline (< 2 ds/m). The total Nitrogen content of the samples fell within the low category whereas available phosphorus content was just adequate. The organic carbon content was also found to be low within all the soil samples but organic matter content ranged from low to moderate. None of the determined parameters fell within high category. The soil samples were also generally low in organic carbon and that could be the reason for the high rate of farmers using soil amendments.

5.2.2 Synthesis of soil quality difference based on soil attributes

It was realised that farmers could not accurately evaluate the quality of the soil category using physical indicators. This was reflected in the generally low cation (Na, K, mg, Ca), Total N and OC content of soils in all farmer soil quality category, none of the parameters determined fell within the high range. This finding is contrary to that of Tesfahunegn *et al.* (2011) where the determined parameters showed that the soils fell within the soil quality categories perceived by the farmers. Though the mean values for most of the soil parameters measured were generally low, it was realised from this study that, the mean values for the parameters in the high soil quality category were high as compared to those in the medium and low categories. Thus, showing an increasing trend with increasing soil

quality category (low-high), which is similar to the findings of Dawoe *et al.* (2012) and Tesfahunegn *et al.* (2011). Nevertheless, they found that “the trend of measured indicator values were well-fitted with the trend of soil quality categories done by local farmers. These studies concluded that the chemical analysis of the soils showed that the quality of soils were similar to that perceived by the local farmers. Thus the soils fell within the farmers’ perceived soil quality ranges particularly for the soil nutrient indicators.” This may be attributed to the farmers acquiring experience on the characteristics of their soils from their many years of farming.

The generally sandy nature of the soil might have accounted for the low level of cations and organic carbon. This could be attributed to their poor retention of nutrients and water (Roy *et al.* 2006), hence influencing the use of soil fertilizers, which is unfortunately not backed by much knowledge on their application.

5.2.3 Soil variability using Principal component analysis

The Principal Component Analysis showed that only four components had significant influence in determining soil quality. The PC 1 had high loadings of Electrical Conductivity, Available Phosphorous, Organic Carbon, Organic matter, Calcium, Magnesium and Potassium. Calcium recorded the highest loading in PC1 while organic carbon and organic matter had the least among those mentioned above. PC2 was made up of high loadings of sand and silt which shows the high influence of the soil texture on soil quality. Silt had high positive loadings which showed a direct influence on the factor loadings whilst sand had a high negative loading which showed an indirect association. PC3 was also a texture factor as it had a high factor loading of Clay. PC4 had a high

negative loading of Sodium which implies an indirect influence of sodium on the soil quality.

Similar to the work of Tesfahunen *et al.* (2011), four principal components were derived with PC2 and PC4 having a similar factor labelling of soil texture factor and ion (Na) factor respectively.

5.2.4 Implications of evaluating farmer knowledge with scientific measurements

The findings of this study showed that, the determined soil quality parameters were not consistent with farmers' classification of soils into high, medium and low soil quality category as the recorded nutrient values were generally low. This gave the impression that though the farmers were quite knowledgeable about their soils, their knowledge might have been in terms of relative productivity of. This is reflected in the increasing values recorded for the various determined parameters.

The findings of Tesfahunen *et al.* (2011) suggest that knowledge on soil quality is probably acquired through the experience and observations of farmers during their years of farming. And as the availability and cost of accessing laboratory facilities for the testing of soil samples is an issue the use of the indigenous soil quality indicators is inevitable.

5.3 Farmers' perception of climate change on soil quality.

From the linear trend analysis of the data from the Ghana Meteorological Agency, it was realised that both rainfall and temperature are increasing. This is in agreement with the assertion of most of the local farmers that temperature has increased over the years. With regards to rainfall, there's been a steady rainfall pattern with slight increase. However, the observed data shows an increase in the variability of the rainfall which is in line with the

UNFCCC assertion that the world is experiencing increase in climate variability (Bodansky, 1993)

Many of the farmers perceived that increase temperature has an influence on the quality of soils. There was a significant association between perception of climate change and the education of farmers. The odds ratio further showed that farmers who had basic education, secondary education and tertiary were more likely to perceive that climate change had effect on the quality of soils compared to those who had no education. This confirm the findings of Deressa *et al.* (2011), who also identified education to significantly influence farmers' perception on climate change.

The perceived effects of climate change on Soil quality included reduction in the productivity of the soils, delay in plant maturity, death of crops and retarded plant growth. These could be explained by the other effects of climate change given by the farmers which included reduction in the soil moisture content, erosion of soil and soil nutrients and also reduction in the presence and processes of soil living organism. This confirms the findings of Kurukulasuriya & Rosenthal (2013) that, the changes in temperature and precipitation is likely to cause changes in soil moisture and content, the timing and length of growing seasons. Classen *et al.* (2015), further explained that temperature changes had effects on soil moisture which influences the rate of diffusion and transportation of nutrients within the soil hence affecting availability of nutrients to plants.

With respect to climate change adaptation measure to Agriculture, most of the farmers did nothing while waiting for the first rains or second rains before planting. Just a few of the farmers practised irrigation farming while others applied mulch to their soils. These had

some similarities to the findings of Deressa *et al.* (2009), in the Nile Basin of Ethiopia, where the climate adaptation methods used by farmers included planting trees, soil conservation, use of different crop varieties, changing planting dates and irrigation with some of them doing nothing. The predominance of most of the farmers doing nothing might be as a result of low promotion of Climate Change adaptation methods in the area, whereas reasons given by farmers in Ethiopia for not putting in place any adaptation strategy included “lack of information, lack of money, shortage of labour, shortage of land, and poor potential for irrigation”

5.4 To assess farmers management practises

The most common farm management practice was the application of soil amendments, followed by crop rotation, change in type of crops cultivated, fallowing, mixed cropping and move to a different land. The least used method is changing the seed variety used. This could be attributed to the lack of knowledge of such available seed options.

Large number of the farmers used soil amendments in their farming activities. This could be attributed to the fact that their soils were mostly sandy, hence had low nutrient retention and as such it was necessary to use soil amendments to improve crop yield and development. Similar to the findings of Diiro *et al.* (2015), the use of soil amendments was found to be significantly associated with the gender of the farmers. They further explained that male-headed households were more likely to adopt fertiliser than female-headed households, as male-headed households could access extension services more easily than female headed households.

Similar to findings by Dawoe *et al.* (2012) in a study conducted in the Ashanti Region of Ghana, the most widely used soil amendment by farmers in Ada is organic. However a lot of farmers also preferred to combine the use of organic and inorganic fertilizer. This is in contrast to the findings of Omari *et al.* (2018) in a study conducted in the Guinea Savannah area of Ghana, where the preferred soil amendment was inorganic fertiliser and a few percentage of farmers combining both organic and inorganic fertiliser. The preference of organic soil amendments could be attributed to the promotion of ORM4 Soil (Farmer-Driven Organic Resource Management to Build Soil Fertility Research) project which is on-going within the study area. The ORM4 Soil project specifically promotes the use of organic soil amendments while researching into soil amendments. The findings on the reason for the choice of soil amendments is similar to the findings of Omari *et al.* (2018), which concluded that farmers' preferred choice of soil amendments stemmed from its ability to produce high yield and its accessibility.

From this study it was also observed that the level of knowledge on the type of soil amendments to use and how to use it was low, this findings of similar to Omari *et al.* (2018) where it also confirmed that the level of knowledge on soil and organic matter management was low among farmer. Though there were indications of the promotion of the use of soil amendments their state of knowledge on the use of them may be as a result of low education on their rightful use as compared to the promotion of their use.

CHAPTER SIX

SUMMARY OF STUDY FINDINGS, CONCLUSION AND RECOMMENDATION

6.1 Summary

Most of the farmers asserted that they were able to tell the quality of their soils using indigenous knowledge they had acquired over their years of farming. Farmers used soil texture, colour, moisture, plant growth and development, crop yield, the presence of some plants and weeds, the presence of some soil living organism and the soil's susceptibility to soil erosion as the indicators in determining the quality of their soils with crop yield and plant development being the most important deciding factor on the quality of their soils.

Comparing the perceived quality of soils by the West District farmers to the laboratory analysis of soils showed that the farmers could not accurately evaluate the quality of their soils using physical indicators. This was reflected in their classification of soils into various soil quality groups (low, medium and high) which was inconsistent with the determined quality of their soils.

Though farmers acknowledged that the climate was changing, most of them did not put much measures in place to adapt to it instead, they either waited for the first rains or the second rains before planting with just a few of them practising irrigation farming and the use of mulch.

The effects they perceived climate change had on their soils include, reduced productivity of the soils, effects on the moisture content of their soils, erosion of soil nutrients, effects on soil texture, retarded plant growth, soil compaction, rapid increase in diseases, death of crops, delay in plant maturity and effects on the soil living organisms. The perception that

climate change had effects on soil quality was found to be associated with education of farmers.

The most common farm management practice was the application of soil amendments, followed by crop rotation, change in crops cultivated, fallowing, mixed cropping and move to a different land. The least used method is changing the seed variety used.

With the application of soil amendments, majority of the farmers preferred a combination of organic and inorganic soil amendments, with organic matter being the most preferred. Majority of the respondents also didn't know the right amount of amendments to apply to their soils, as most of them applied as much as they could with a few depending on the advice of their extension officers.

6.2 Conclusion

The use of indigenous soil quality indicators in determining the quality of soils is inevitable, as it is the most convenient means of assessing soil quality by farmers. These indigenous soil quality indicators the farmers often use are mostly limited to factors visible to the eye such soil colour, plant growth and development and crop yield. Regardless of they been used globally, physicochemical test conducted on soil samples indicated that farmers in this study area were not able to accurately predict soil quality but were rather able to predict relative soil quality as compared to studies conducted by other researchers who found farmers to have adequate knowledge of their soils.

Farmers in this study exhibited knowledge of the changing climatic conditions but did not put in place enough measures to deal with it meanwhile farmers asserted that they applied soil amendments, they had inadequate knowledge in the application of the various soil

amendments. This therefore mandates an intensification of education and extension services to address the issue of soil quality prediction, climate change adaptation measures as well as the appropriate application of soil amendments.

6.3 Recommendation

This study recommends that Ministry of Food and Agriculture through the district Agricultural offices assist local farmers to periodically test their soils at the laboratory at subsidised prices. This is to assist them to know the actual state of their soils which will go a long way in helping them choose the appropriate farm management practises which will ensure continuous high yield and hence ensure food security

This study also recommends that the promotion of farm management practice should be accompanied by effective education on their rightful use and application. In addition, education on the use of soil amendments should be intensified in order to ensure that farmers do not over use or under use them, so as to ensure efficiency.

As the level of climate change adaptation practices was low in the study area, the promotion of climate smart agriculture should be intensified in the area. This will ensure increase in productivity in the face of climate change.

Futures study should concentrate on how each of the significant nutrient factors actually indicates soil quality.

It was realised from the study that most of the farmers used the presence of some plants and weeds as soil quality indicators and as such this study also suggest that more research be done on the plants and weeds species that could be used as indicators of soil quality

since if this is effectively done will provide one of the easiest ways of identifying the quality of soils and also help in realising some other benefits of some plants species.

REFERENCE

- Adams, R. M. (1989). Global climate change and agriculture: an economic perspective. *American Journal of Agricultural Economics*, 71(5), 1272-1279.
- Adams, R. M., Hurd, B. H., Lenhart, S., & Leary, N. (1998). Effects of global climate change on agriculture: an interpretative review. *Climate research*, 11(1), 19-30.
- Agegnehu, J. G. (2017). *Biochar, Compost and Biochar-Compost: Effects on Crop Performance, Soil Quality and Greenhouse Gas Emissions in Tropical Agricultural Soils* (Doctoral dissertation, James Cook University).
- Arshad, M. A., & Martin, S. (2002). Identifying critical limits for soil quality indicators in agro-ecosystems. *Agriculture, Ecosystems & Environment*, 88(2), 153-160. doi:[https://doi.org/10.1016/S0167-8809\(01\)00252-3](https://doi.org/10.1016/S0167-8809(01)00252-3)
- Bationo, A., Kihara, J., Kimetu, J., & Waswa, B. (Eds.). (2007). *Advances in integrated soil fertility management in sub-Saharan Africa: Challenges and opportunities* (p. 1091). Dordrecht: Springer.
- Bodansky, D. (1993). The United Nations framework convention on climate change: a commentary. *Yale J. Int'l l.*, 18, 451.
- Boggs, J. (2016). Soil Basics. *Ohio State University Extension*, 6-8-16.
- Bray, R. H., & Kurtz, L. T. (1945). Determination of total and organic and available forms of phosphorus in soils. *Journal of Soil Science*, 59, 39-45
- Brejda, J. J., Moorman, T. B., Karlen, D. L., & Dao, T. H. (2000). Identification of regional soil quality factors and indicators I. Central and Southern High Plains. *Soil Science Society of America Journal*, 64(6), 2115-2124.
- Change, I. P. O. C. (2001). *Climate change 2007: Impacts, adaptation and vulnerability. Geneva, Suíça.*
- Chesworth, W. (1982). Late Cenozoic geology and the second oldest profession. *Geoscience Canada*, 9(1).

- Classen, A. T., Sundqvist, M. K., Henning, J. A., Newman, G. S., Moore, J. A., Cregger, M. A., ... & Patterson, C. M. (2015). Direct and indirect effects of climate change on soil microbial and soil microbial-plant interactions: What lies ahead?. *Ecosphere*, 6(8), 1-21.
- Clay, E. W., & Robinson, H. R. (1838). Executive mercy/Marcy and the Bambers [graphic]. N.Y.: Printed & publ'd by H.R. Robinson,.
- Darwin, R., Tsigas, M. E., Lewandrowski, J., & Raneses, A. (1995). *World agriculture and climate change: Economic adaptations*. Retrieved from
- Dawoe, E. K., Quashie-Sam, J., Isaac, M. E., & Oppong, S. K. (2012). Exploring farmers' local knowledge and perceptions of soil fertility and management in the Ashanti Region of Ghana. *Geoderma*, 179-180, 96-103. doi:<https://doi.org/10.1016/j.geoderma.2012.02.015>
- Day, P. R. (1965). Particle fractionation and particle-size analysis. In C. A. Black, D. D. Evans, J. L. White, E. L. Ensminger, & F. E. Clark (Eds.), *Methods of soil analysis, Part 1* (pp. 545–567).
- Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change*, 19(2), 248-255. doi:<https://doi.org/10.1016/j.gloenvcha.2009.01.002>
- Diirro, G. M., Ker, A. P., & Sam, A. G. (2015). The role of gender in fertiliser adoption in Uganda. *African Journal of Agricultural and Resource Economics*, 10(2), 117-130.
- FAO. (1974). *The Euphrates Pilot Irrigation Project: Methods of soil analysis. Gated Soil Laboratory (A laboratory manual)*. Rome:
- Food and Agriculture Organization. FAO. (1974). Key to the FAO Soil Units. "*Legend of the Soil Map of the World Extract from "Legend of the Soil Map of the World"*", 1974, UNESCO, Paris. doi:<http://www.fao.org/soils-portal/soil-survey/soil-classification/fao-legend/key-to-the-fao-soil-units/en/>

- FAO. (n.d.). Chemical Properties (Publication no. <http://www.fao.org/soils-portal/soil-survey/soil-classification/numerical-systems/chemical-properties/en/>). Retrieved 12/7/2018, from Food and Agricultural Organisation
- FAO. (1998). *World reference base for soil resources* (Vol. 3): Food & Agriculture Org.
- Fosu-Mensah, B. Y., Vlek, P. L., & MacCarthy, D. S. (2012). Farmers' perception and adaptation to climate change: a case study of Sekyedumase district in Ghana. *Environment, Development and Sustainability*, 14(4), 495-505.
- Ghana Statistical Service. (2014). 2010 Population and Housing Census: District Analytical Report of ADA West.
- Ghana Statistical Service. (2017). *Provisional 2016 Annual Gross Domestic Product, April 2017 edition*. doi: <https://www.statsghana.gov.gh>
- Griggs, D., Stafford-Smith, M., Gaffney, O., Rockström, J., Öhman, M. C., Shyamsundar, P., . . . Noble, I. (2013). Policy: Sustainable development goals for people and planet. *Nature*, 495(7441), 305-307.
- Hill, S. B., & Ramsay, J. (1977). Weeds as indicators of soil conditions. *The McDonald Journal*, 38(6), 8-12.
- Howden, S. M., Soussana, J.-F., Tubiello, F. N., Chhetri, N., Dunlop, M., & Meinke, H. (2007). Adapting agriculture to climate change. *Proceedings of the national academy of sciences*, 104(50), 19691-19696.
- Karlen, D. L., Mausbach, M. J., Doran, J. W., Cline, R. G., Harris, R. F., & Schuman, G. E. (1997). Soil Quality: A Concept, Definition, and Framework for Evaluation (A Guest Editorial). *Soil Science Society of America Journal*, 61(1), 4-10. doi:10.2136/sssaj1997.03615995006100010001x
- Kjeldahl, J. (1883). Neue Methode zur Bestimmung des Stickstoffs in organischen Körpern. Fresenius' Journal of Analytical Chemistry, 22(1), 366–382

- Krüger, I., Chartin, C., Wesemael, B. v., Malchair, S., & Carnol, M. (2017). Integrating biological indicators in a Soil Monitoring Network (SMN) to improve soil quality diagnosis - a case study in Southern Belgium (Wallonia). *Biotechnologie, Agronomie, Société et Environnement*, 21(3), 219-230.
- Kurukulasuriya, P., & Rosenthal, S. (2013). Climate change and agriculture: A review of impacts and adaptations.
- Lima, A. C. R., Hoogmoed, W. B., Brussaard, L., & Sacco dos Anjos, F. (2011). Farmers' assessment of soil quality in rice production systems. *NJAS - Wageningen Journal of Life Sciences*, 58(1), 31-38. doi:<https://doi.org/10.1016/j.njas.2010.08.002>
- Maddison, D. (2007). *The perception of and adaptation to climate change in Africa*: The World Bank.
- Madison, WI: American Society of Agronomy. Deressa, T. T., Hassan, R. M., & Ringler, C. (2011). Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. *The Journal of Agricultural Science*, 149(1), 23-31.
- Mapfumo, P., & Giller, K. (2001). *Soil fertility management strategies and practices by smallholder farmers in semi-arid areas of Zimbabwe*. Retrieved from
- McCarthy, J. J., Canziani, O. F., Leary, N. A., Dokken, D. J., & White, K. S. (2001). *Climate change 2001: impacts, adaptation, and vulnerability: contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change* (Vol. 2): Cambridge University Press.
- McKeague, J. A. (1978). *Manual on Soil Sampling and Methods of Analysis* (Vol. Canada Soil Survey Committee. Subcommittee on Methods of Analysis): Canadian Society of Soil Science.
- Mirzaei-Aghsaghali, A., & Maheri-Sis, N. (2008). Nutritive value of some agro-industrial by-products for ruminants-A review. *World J. Zool*, 3(2), 40-46.
- Naiman R. J., Décamps H., McClain M E.& Likens G E. (2005).4 - *Structural Patterns*, Academic Press, 79-123. <https://doi.org/10.1016/B978-012663315-3/50005-8>.

- Nations, A. O. f. t. U. (1998). *World reference base for soil resources* (Vol. 3): Food & Agriculture Org.
- Nearing, M. A., Pruski, F. F., & O'neal, M. R. (2004). Expected climate change impacts on soil erosion rates: a review. *Journal of soil and water conservation*, 59(1), 43-50.
- Nelson, G. C., Rosegrant, M. W., Koo, J., Robertson, R., Sulser, T., Zhu, T., . . . Batka, M. (2009). *Climate change: Impact on agriculture and costs of adaptation* (Vol. 21): Intl Food Policy Res Inst.
- Normaniza, O., Aimee, H., Ismail, Y., Tan, G., & Rozainah, M. (2018). Promoter Effect Of Microbes In Slope Eco-Engineering: Effects On Plant Growth, Soil Quality And Erosion Rate At Different Vegetation Densities. *Applied Ecology And Environmental Research*, 16(3), 2219-2232.
- Okonya, J. S., Syndikus, K., & Kroschel, J. (2013). Farmers' perception of and coping strategies to climate change: Evidence from six agro-ecological zones of Uganda. *Journal of Agricultural Science*, 5(8), 252.
- Piao, S., Ciais, P., Huang, Y., Shen, Z., Peng, S., Li, J., . . . Ding, Y. (2010). The impacts of climate change on water resources and agriculture in China. *Nature*, 467(7311), 43.
- Proffitt, T. (2014). Assessing soil quality and interpreting soil test results. *Recuperado de [www. winewa. asn. au](http://www.winewa.asn.au)*.
- Roy, R., Finck, A., Blair, G., & Tandon, H. (2006). Plant nutrition for food security. A *guide for integrated nutrient management*. *FAO Fertilizer and Plant Nutrition Bulletin*, 16, 368.
- Schoenholtz, S. H., Miegroet, H. V., & Burger, J. A. (2000). A review of chemical and physical properties as indicators of forest soil quality: challenges and opportunities. *Forest Ecology and Management*, 138(1), 335-356. doi:[https://doi.org/10.1016/S0378-1127\(00\)00423-0](https://doi.org/10.1016/S0378-1127(00)00423-0)

- Seneviratne, S. I., Corti, T., Davin, E. L., Hirschi, M., Jaeger, E. B., Lehner, I., . . . Teuling, A. J. (2010). Investigating soil moisture–climate interactions in a changing climate: A review. *Earth-Science Reviews*, 99(3), 125-161. doi:<https://doi.org/10.1016/j.earscirev.2010.02.004>
- Tesfahunegn, G. B., Tamene, L., & Vlek, P. L. G. (2011). Evaluation of soil quality identified by local farmers in Mai-Negus catchment, northern Ethiopia. *Geoderma*, 163(3), 209-218. doi:<https://doi.org/10.1016/j.geoderma.2011.04.016>
- Tesfahunegn, G. B., Tamene, L., Vlek, P. L., & Mekonnen, K. (2016). Assessing Farmers' Knowledge of Weed Species, Crop Type and Soil Management Practices in Relation to Soil Quality Status in Mai-Negus Catchment, Northern Ethiopia. *Land degradation & development*, 27(2), 120-133.
- Tesfahunegn, G. B., Mekonen, K., & Tekle, A. (2016). Farmers' perception on causes, indicators and determinants of climate change in northern Ethiopia: implication for developing adaptation strategies. *Applied Geography*, 73, 1-12.
- Thomas, G. W. (1996). Soil pH and soil acidity. *Methods of Soil Analysis Part 3—Chemical Methods*(methodsofsoilan3), 475-490.
- Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R., & Polasky, S. (2002). Agricultural sustainability and intensive production practices. *Nature*, 418(6898), 671.
- Walkley, A., & Black, I. A. (1934). An examination of the Degtjaref method for determining soil organic matter, and a proposed modification of the chronic acid titration method. *Journal of Soil Science*, 37, 29–38
- Warkentin, B. P. (1995). The changing concept of soil quality. *Journal of soil and water conservation*, 50(3), 226-228.
- Winklerprins, A. M. G. A. (1999). Insights and applications local soil knowledge: A tool for sustainable land management. *Society and Natural Resources*, 12(2), 151-161. doi:10.1080/089419299279812

- Yaro, J. A. (2013). The perception of and adaptation to climate variability/change in Ghana by small-scale and commercial farmers. *Regional Environmental Change*, 13(6), 1259-1272.
- Zhen, L., Zoebisch, M. A., Chen, G., & Feng, Z. (2006). Sustainability of farmers' soil fertility management practices: A case study in the North China Plain. *Journal of Environmental Management*, 79(4), 409-419.
doi:<https://doi.org/10.1016/j.jenvman.2005.08.009>

APPENDIX

Questionnaire

UNIVERSITY OF GHANA, LEGON

INSTITUTE FOR ENVIRONMENT AND SANITATION STUDIES

Topic: Farmers' Perception on Soil Quality Indicators.

This questionnaire is designed to aid the collection of data to research into the above topic. It would be much appreciated if you could help complete this questionnaire. Responses would be treated confidentially and would be used strictly for academic purposes.

Name of the enumerator..... Date..... Sig.....
District..... Zone..... Location of farm.....

Please tick [✓] or write the correct answers where appropriate.

SECTION A: Characteristics

1. Gender a) Male [] b) Female []
2. Age a)Below 15yrs [] b)15-24yrs [] c)25-34yrs [] d)35-44yrs [] e)45yrs &above[]
3. Marital status a) Single [] b) Married[] c) Divorced [] d)Separated [] e)Widow []
4. Level of education a)None[] b)Basic[] c)Secondary[] d)Tertiary[] e)Other(specify).....
5. Religion: a) Christian [] b) Islamic [] c) Traditional [] d) Others (please specify).....
6. How long have you been farming? a) Less than 5 yrs [] b) 5-10 [] c) 11-15 [] d)16-20[] e)21-25[] f)26-30[] g)over 30 years [] other (please specify)
7. How do you obtain the land for cultivation? a) Family land [] b) Owns the land [] c) Rents the land [] d) Share cropping [] e) Other (please specify).....

8. What is the main type of crop do you grow? a)grains b)fruits c) Legumes
d)Vegetables e) tubers d) mixed cropping (specify).....
9. What is your total land size? a)Less than 1 acre b)2-3 acres c)4-5 acres c)over 5acres
10. Is farming your major source of income? Yes [] No []
11. If no, what is your main source of income? a) Government sector [] b) Private sector
[] c) Self employed [] d) Donations [] e) others (please specify).....
12. What type of farming methods do you employ? a)Traditional [] b) Mechanised []
13. Are you into subsistence or commercial farming? a)Subsistence [] b) Commercial
[]

Section B: Indigenous soil quality indicators.

14. Are you able to tell the differences in the type of soils? Yes [] No[]
15. How will you describe the type of soil on your farm? a)sandy b)clayey c)loam
d)silt
16. How do you determine the soil quality of your farm? a) Scientific testing b) Physical
characteristics c) others, specify.....
17. What is the main reason for your choice? a)easier to use b)no cost involved c)very
accurate d)readily available e) learnt from experience f) passed on from ancestors g)
others, specify.....
18. What indicators do you use to assess soil quality?

INDICATORS	YES	N O	INDICTORS	YES	NO
a) Soil colour			f) Soil texture		
b)Presence of some soil living organisms (specify)			g) Presence of some plants/weeds(specify).....		
c) Soil moisture			h)Thickness of top soil		
d) Plant growth & development			i) Erosion		
e) Crop yield			j) Others specify.....		

19. Which of the mentioned indicators is the most important to you?
20. Are you able to tell if the soil quality is deteriorating? a)Yes [] b) No[]

21. If yes, how?

INDICATORS	YES	N O	INDICATORS	YES	N O
a)changes in soil colour			f)Changes in plants/weeds on the soil		
b)changes in soil texture			g)Changes in thickness of top soil		
c)Plant Growth and development			h)reduction or absence soil living organisms		
d)Reduction in crop yield			i)erosion		
e)Reduction in soil moisture			j)others specify.....		

22. Which of the following does your knowledge on your soil affect?

ACTIVITY	YES	NO	ACTIVITY	YES	NO
a) What to plant			d) What soil amendment to use		
b) Where to plant			e) What tools to use		
c) How to plant			f) Others		

SECTION C: *Farmers perception on the effect of climate change on soil quality*

23. Have you heard of Climate Change? Yes [] No []

24. If yes, do you think it has an effect on soil quality? Yes [] No []

25. If yes, how does it affect soil

quality?

26. How do you deal with this effect? a) I do nothing b) mulch c) irrigation
 d) I wait for the first rain before planting e)Others (please specify)

SECTION D: *Soil management practices*

27. What do you do when you think your soil has lost its fertility?

ACTIVITY	YES	NO		YES	NO
a) fallow			e) Change seed variety		
b) move to a different land			f) mixed cropping		
c) apply soil amendments			g) crop rotation		
d) change the type of crop			h) Others (specify).....		

28. Do you use soil amendments? Yes [] No []

29. Which soil amendment do you apply? a) organic b) Inorganic c) both

30. If both which do you prefer? a) organic b) Inorganic

31. Why your choice in question 29/30 a) less expensive b) readily available c) easy to use d) increases yield rapidly e) Others (please specify)
.....

32. How do you know what amount of amendment to apply? a) Advise from extension officer b) as much as I can c) No specific measurement d) depending on the level of the previous yield e) others (please specify).....

Comments

.....

THANK YOU

